DEPARTMENT OF METALLURGICAL ENGINEERING
Library Number: 3
Return this book to
Cupboard:
Shelf: F.
All books are to be signed for in the loan book when borrowed, and when returned.
Books must be returned within One Week, unless special permission is given for a longer loan.

UNIVERSITY OF TORONTO
MAR 7 - 1924
DEPT. OF
MATALLURGICAL ENGINEERING

P
Technol
A

INDEX

Transactions American Society for Steel Treating

Volume III
October, 1922—June, 1923

187929
26/2/24

Published by
American Society for Steel Treating
4600 Prospect Avenue
Cleveland
Ohio

INDEX

TS
300
A76
v.3

TRANSACTIONS
AMERICAN SOCIETY FOR STEEL TREATING
VOLUME III
OCTOBER, 1922—JUNE, 1923

	Pages
October	1-122
November	123-276
December	277-360
January	361-476
February	477-590
March	591-704
April	705-792
May	793-900
June	901-998

INDEX OF AUTHORS

Volume III—TRANSACTIONS of American Society for Steel Treating
October, 1922—June, 1923

A

Alfred, F. H. 175
Allen, R. J. 43

B

Blasko, Edmund 103
Boylston, H. M. 549
Briggs, H. K. 851
Burton, Marion L. 185

C

Calkins, William G. 239
Clements, F. O. 415
Cope, L. S. 808
Corse, W. M. 231

D

DeLong, B. H. 567
Demorest, D. J. 556
Diederichs, W. J. 624, 918
Dunlap, W. M. 624

E

Egeberg, B. 422

F

Flinn, Alfred D. 218
French, H. J. 640
Frydendall, A. D. 824
Fuller, T. S. 94

G

German, H. M. 489
Guthrie, Robert G. 710

H

Hallimond, A. F. 931
Hayes, Anson 624, 918
Herdegen, R. T. 841
Hoffman, N. B. 436
Hollnagel, H. P. 480
Holz, Herman A. 367
Honda, Kotaro. 729

I

Idei, Sakae 729
Ipsen, C. L. 720

J

Janitzky, E. J. 335

K

Klopsch, O. Z. 855
Knerr, Horace C. 13
Knight, O. A. 545, 758
Knowlton, H. B. 537

L

Lewton, R. E. 944
Lynch, T. D. 833

M

Marshall, L. K. 90
Mathews, John A. 393, 534
Matsushita, Tokujiro 729
Medwedeff, M. H. 928
Merten, W. J. 833

N

Nelson, T. Holland 279
Newcomb, R. W. 98

P

Peebles, H. G. 907

R

Rawdon, Henry S. 648
Roberts, H. F. 855

S

Scott, Howard 593
Smart, C. F. 299
Smith, J. Weaver 396
Stedman, E. G. 740
Stout, Wm. B. 226
Sveshnikoff, W. W. 502

T

Tiemann, H. P. 566
Tour, Sam 245

U

Unger, J. S. 430

V

Vanick, J. S. 196, 502

W

Watson, J. M. 557
White, A. E. 386, 555, 751

F

Fatigue Tests of Spring Steels—*R. E. Lewton* 944
Federal and State Research Agencies—*W. M. Corse* 231
Forged Milling Cutter; Advantages of—*William G. Calkins* 239
Forging Practice for Automobile Parts—*R. T. Herdegen* 841
Formation of Pearlite, Troostite, and Martensite—Delayed Crystallization in the Carbon Steels—*A. F. Hallimond* 931
Fundamentals of Research—*F. O. Clements* 415
Furnace Melting Practice; Electric—*E. G. Stedman* 740
Furnaces; A New Type Automatic Temperature Regulator and its Application to Heat Treating Furnaces—*R. W. Newcomb* 98
Furnaces; Combustion as it Pertains to Industrial Heat Treatment Furnaces—*A. D. Frydendall* 824
Furnaces for Steel Treating; Selection of—*C. L. Ipsen* 720

G

Gas Useful in Heat Treating Room—*J. Weaver Smith* 396
Graphitization of White Cast Iron and a Theory for the Mechanism of same; Experiments on—*Anson Hayes, W. J. Diedrichs and W. M. Dunlap* 624

H

Hardness; Testing of Metals for—Contribution to Symposium on Hardness Testing—*H. M. German* 489
Hardness of Metals; Testing of; a Contribution to Symposium on Hardness Testing—*H. M. German* 489
Hardness Testing; Symposium on 480
Hardness Tests; Significance of; Contribution to Symposium on Hardness Testing—*H. P. Hollnagel* 480
Heat Regulator and its Application to Heat Treating Furnaces; A New Automatic Type—*R. W. Newcomb* 98
Heat Treatment Furnaces; Combustion as it Pertains to Industrial Furnaces—*A. D. Frydendall* 824
Heat Treating; Salt Baths for—*Sam Tour* 245
Heat Treating; Education of Machinists and Tool Makers in Heat Treating—*H. B. Knowlton* 537
Heat Treating Furnaces; A New Type Automatic Temperature Regulator and its Application to—*R. W. Newcomb* 98
Heat Treating Room; Gas Useful in—*J. Weaver Smith* 396
Heat Treatment of Cast Steel for Hydroelectric Power Machinery—*B. Egeberg* ... 422
High-Carbon Steels; Effect of High-Temperature Quenching on the Microstructure of—*Howard Scott* 593
High Grade Crucible Steel; Comparison of American and English Methods of of Producing—*T. Holland Nelson* 279
High-Speed Steel; Carbide Segregation in High-Speed Steel—*A. E. White* 386
High-Speed Tool Steels; Bibliography of 47
High-Temperature Quenching; Effect of, on the Microstructure of High-Carbon Steels—*Howard Scott* 593
High Temperatures on Malleable Iron; Tests Showing the Effect of—*T. D. Lynch and W. J. Merten* 833
Hollow Rock Drill Steel, Metallographic Study of, as the Steel is Influenced by the Method of Manufacture—*N. B. Hoffman* 436
Hydroelectric Power Machinery; Heat Treatment of Cast Steel for—*B. Egeberg* .. 422

I

Industry; The Need for More Practical Information in Industry—*J. S. Unger* .. 430
Industrial Heat Treatment Furnaces; Combustion in—*A. D. Frydendall* 824
Information in Industry; the Need for More Practical Information—*J. S. Unger* .. 430
Information on Duralumin—A Digest—*Horace C. Knerr* 13
Ingot Iron; Migration of Carbon from Steel to Ingot Iron—*O. Z. Klopsch and H. F. Roberts* 855
Inspection and Manufacture of Leaf Springs—*H. G. Peebles* 907
Inspection of Steel for Automobile Use; Some Notes on—*R. J. Allen* 43
Inverse-Rate Method of Thermal Analysis; A Recording Chronograph for—*H. J. French* 640
Iron; Tests Showing the Effect of High Temperatures on Malleable Iron—*T. D. Lynch and W. J. Merten*..... 833
Iron and Steel; Corrosion of—*T. S. Fuller*..... 94

L

Leaf Springs; Fatigue Tests of—*R. E. Lewton*..... 944
Leaf Springs; Manufacture and Inspection of—*H. G. Peebles*..... 907
Light; The Use of Various Kinds of Light in Metallography—*Robert G. Guthrie* 710

M

Machinery; Heat Treatment of Cast Steel for Hydroelectric Power Machinery—*B. Egeberg*..... 422
Machinists and Tool Makers; Education in Heat Treating for—*H. B. Knowlton*.. 537
Malleable Iron; Tests Showing the Effect of High Temperatures on—*T. D. Lynch and W. J. Merten*..... 833
Manipulation of Tool Steel—*L. K. Marshall*..... 90
Manufacture and Inspection of Leaf Springs—*H. G. Peebles*..... 907
Manufacture; Metallographic Study of Hollow Rock Drill Steel, as Influenced by the Method of Manufacture—*N. B. Hoffman*..... 436
Martensite; Delayed Crystallization in the Carbon Steels; the Formation of Pearlite, Troostite and Martensite—*A. F. Hallimond*..... 931
Mechanical Properties of Some Chrome-Vanadium Steels—*J. S. Vanick*..... 196
Mechanism of Graphitization; Experiments on the Rapid Graphitization of White Cast Iron and a Theory for same—*Anson Hayes, W. J. Diederichs and W. M. Dunlap* 624
Melting Practice; Electric Furnace—*E. G. Stedman*..... 740
Metals; Structure and Related Properties of—*Henry S. Rawdon*..... 648
Metallographic Study of Hollow Rock Drill Steel, as Influenced by the Method of Manufacture—*N. B. Hoffman*..... 436
Metallography; The Use of Various Kinds of Light in Metallography—*Robert G. Guthrie* 710
Metallurgical Course for Engineers—*H. M. Boylston*..... 549
Metallurgical Education; Symposium on..... 534
Metallurgical Education—A Contribution to Symposium on Metallurgical Education—*B. H. DeLong*..... 567
Metallurgical Education; Notes on—*John A. Mathews*..... 534
Metallurgy in the Modern Shop—*M. H. Medwedeff*..... 928
Metallurgical Work; Practical Aspects of, A Contribution to Symposium on Metallurgical Education—*J. M. Watson*..... 557
Method of Manufacture; Metallographic Study of Hollow Rock Drill Steel, as Influenced by the—*N. B. Hoffman*..... 436

Method of Thermal Analysis; A Recording Chronograph for the Inverse-Rate Method—*H. J. French* 640
Microstructure of High-Carbon Steels; Effect of High-Temperature Quenching on the—*Howard Scott* 593
Migration of Carbon from Steel to Ingot Iron—*O. Z. Klopsch and H. F. Roberts* 855
Milling Cutter; Advantages of the Forged Milling Cutter—*William G. Calkins*.... 239
Modification of the Equilibrium Diagram; Evidences of a Carbon-Iron Eutectoid and Resulting—*Anson Hayes and W. J. Diederichs* 918

N

Need for More Practical Information in the Industry—*J. S. Unger* 430
New Type of Automatic Temperature Regulator and its Application to Heat Treating Furnaces—*R. W. Newcomb* 98
Notes on Metallurgical Education—*John A. Mathews* 534
Notes on the Inspection of Steel for Automobile Use—*R. J. Allen* 43

O

On the Cause of Quenching Cracks—*Kotaro Honda, Tokujiro Matsushita and Sakae Idei* 729

P

Pearlite; Delayed Crystallization in the Carbon Steels; the Formation of Pearlite, Troostite and Martensite—*A. F. Hallimond* 931
Polarized Light; Use of in Metallography—*Robert G. Guthrie* 710
Pouring Temperatures of Steel Castings—*H. K. Briggs* 851
Power Machinery; Heat Treatment of Cast Steel for Hydroelectric Power Machinery—*B. Egeberg* 422
Practice; Electric Furnace Melting Practice—*E. G. Stedman* 740
Practical Aspects of Metallurgical Work—A Contribution to Symposium on Metallurgical Education—*J. M. Watson* 557
Properties and Commercial Possibilities of Duralumin—*Wm. B. Stout* 226
Properties of Metals; the Structure and Related Properties of—*Henry S. Rawdon* 648

Q

Quality Steel; Relation of Top Discard to Quality—*A. E. White* 751
Quenching; Effect of High-Temperature Quenching on the Microstructure of High-Carbon Steels—*Howard Scott* 593
Quenching Cracks; the Cause of—*Kotaro Honda, Tokujiro Matsushita and Sakae Idei* 729

R

Railroads; What is the Matter with the American Railroads Today/—*F. H. Alfred* 175
Recent Researches on the Elastic Limit—*Herman A. Holz* 367
Recording Chronograph for the Inverse-Rate Method of Thermal Analysis—*H. J. French* 640
Researches on the Elastic Limit—*Herman A. Holz* 367
Research; The Executive and Research—*John A. Mathews* 393
Research; Some Fundamentals of—*F. O. Clements* 415
Research Agencies; Federal and State—*W. M. Corse* 231
Research for Engineering Societies—*Alfred D. Flinn* 218

S

Salt Baths for Heat Treating—*Sam Tour* 245
Segregation; Carbide Segregation in High-Speed Steel—*A. E. White* 386
Selection of Electric Furnaces for Steel Treating—*C. L. Ipsen* 720
Shop; Metallurgy in the Modern Shop—*M. H. Medwedeff* 928
Significance of Hardness Tests—*H. P. Hollnagel* 480
Societies; Research for Engineering—*Alfred D. Flinn* 218
Some Fatigue Tests of Spring Steels—*R. E. Lewton* 944
Some Fundamentals of Research—*F. O. Clements* 415
Springs; Manufacture and Inspection of Leaf Springs—*H. G. Peebles* 907
Spring Steels; Fatigue Tests of—*R. E. Lewton* 944
State and Federal Research Agencies—*W. M. Corse* 231
Steel; Carbide Segregation in High-Speed Steel—*A. E. White* 386
Steel; Comparison of American and English Methods of Producing High Grade Crucible Steel—*T. Holland Nelson* 279
Steel, as Influenced by the Method of Manufacture; Metallographic Study of Hollow Rock Drill Steel—*N. B. Hoffman* 436
Steel; Manipulation of Tool Steel—*L. K. Marshall* 90
Steel; Migration of Carbon from Steel to Ingot Iron—*O. Z. Klopsch and H. F. Roberts* 855
Steel; Top Discard in its Relation to Quality—*A. E. White* 751
Steel Castings; Pouring Temperatures of—*H. K. Briggs* 851
Steel for Automobile Use; Some Notes on the Inspection of—*R. J. Allen* 43
Steel for Hydroelectric Power Machinery; Heat Treatment of Cast Steel for—*B. Egeberg* 422
Steel and Iron; Corrosion of—*T. S. Fuller* 94
Steel is Steel—*C. F. Smart* 299
Steel Treaters—"We are Guilty"—*Edmund Blasko* 103
Steel Treating; Selection of Electric Furnaces for—*C. L. Ipsen* 720
Steels; Bibliography of High-Speed Tool Steels 47
Steels; Delayed Crystallization in the Carbon Steels; the Formation of Pearlite, Troostite and Martensite—*A. F. Hallimond* 931
Steels; Effect of High-Temperature Quenching on the Microstructure of High-Carbon Steels—*Howard Scott* 593
Steels; Mechanical Properties of Some Chrome-Vanadium Steels—*J. S. Vanick* .. 196
Steels; Thermal Transformations in Some Chrome-Vanadium Steels—*J. S. Vanick and W. W. Sveshnikoff* 502
Structure and Related Properties of Metals—*Henry S. Rawdon* 648
Study of Hollow Rock Drill Steel, as Influenced by the Method of Manufacture—*N. B. Hoffman* 436
Symposium on Hardness Testing 480
Symposium on Metallurgical Education 534

T

Technical Session; Discussions of Papers Presented Before the Technical Session of the Detroit Convention of the Society, Thursday Morning, October 5, 1922 954
Temperature Regulator and its Application to Heat Treating Furnaces; A New Type—*R. W. Newcomb* 98
Testing; Symposium on Hardness Testing 480
Testing of Metals for Hardness, A Contribution to Symposium on Hardness Testing—*H. M. German* 489

Tests Showing the Effect of High Temperatures on Malleable Iron—*T. D. Lynch and W. J. Merten* 833
Tests; Some Fatigue Tests of Spring Steels—*R. E. Lewton* 944
Tests; Significance of Hardness—*H. P. Hollnagel* 480
That Mind of Yours—*Marion L. Burton* 185
Theory for the Mechanism of Graphitization; Experiments on the Rapid Graphitization of White Cast Iron—*Anson Hayes, W. J. Diederichs and W. M. Dunlap* 624
Thermal Analysis; A Recording Chronograph for the Inverse-Rate Method of—*H. J. French* 640
Thermal Transformations in Some Chrome-Vanadium Steels—*J. S. Vanick and W. W. Sveshnikoff* 502
Tool Makers; Education in Heat Treating for Machinists and Tool Makers—*H. B. Knowlton* 537
Tool Steel Manipulation—*L. K. Marshall* 90
Tool Steels; Bibliography of High-Speed Tool Steels 47
Top Discard in Its Relation to Quality—*A. E. White* 751
Transformations in Some Chrome-Vanadium Steels; Thermal—*J. S. Vanick and W. W. Sveshnikoff* 502
Troostite; Delayed Crystallization in the Carbon Steels—The Formation of Pearlite, Troostite and Martensite—*A. F. Hallimond* 931

U

Use of Various Kinds of Light in Metallography—*Robert G. Guthrie* 710

W

What is the Matter with the American Railroads Today?—*F. H. Alfred* 175

TRANSACTIONS

of the

American Society for Steel Treating

Vol. III Cleveland, October 1922 No. 1

PROGRESS

THE September or Convention issue of TRANSACTIONS completed Volume II. More than twelve hundred pages of reading matter have been included in this volume, which is an increase of approximately sixty-three per cent over the content of Volume I.

While we are of the opinion that quantity is not a substitute for quality we feel that such is not the case with the type of papers which have been presented in Volume II. The quality of the papers which appeared in Volume I were of exceptionally high order, and those appearing in Volume II while of equal calibre cover a somewhat broader field of endeavor. Also the number of papers contributed during the past year has exceeded the number previously received.

It is hoped that the yearly presentation of the Howe medal will inspire more of our capable metallurgists, physicists and chemical engineers to present some of the results of their researches in the realm of science.

PRACTICE AND THEORY

THE frequent expression "Oh, that is alright in theory but it will not work in practice" is absurd, because a little reflection on the matter will show that whatever will not work out in practice is not right in theory, and that a theory is not wrong simply because it cannot be made to work by the one who formulates it.

In the case of metallurgists or heat treating department supervisors, as in the case of other executives, such as the factory manager or production manager, there are many places where their theories must be put into practice. Upon the skilled worker usually depends the success or failure of a given theory because the "man at the fire" usually has acquired the ability and become trained in the art of heat treating metals whereas his superior has not always had this training. However, the lack of ability on the part of the author of an idea or combination of ideas, to execute his theory does not stamp him as incompetent nor does it mark his theory as non-practical. Many theories which seemingly are not practical have been the foundation of huge commercial developments.

REPORT OF CONVENTION

THE October TRANSACTIONS goes to press on the eve of our fourth annual convention and exposition. The November issue will contain the report of the activities of this the largest of our conventions.

R. J. ALLEN
First Vice President of the Society

W. S. BIDLE
Second Vice President of the Society

W. H. EISENMAN
National Secretary of the Society

J. V. EMMONS
National Treasurer of the Society

A. E. WHITE
Past President
National Director of the Society

J. J. CROWE
National Director of the Society

F. P. GILLIGAN
Past President
National Director of the Society

S. M. HAVENS
National Director of the Society

by the membership for National Officers of the American Society for Steel Treating.

These ballots were received by the Committee, opened, examined, and counted in the National Headquarters of the Society at 4600 Prospect Avenue, Cleveland, Ohio.

The signature of each voting member written on the outside of the envelope had previously been verified by Secretary, W. H. Eisenman, and found to be correct.

The tabulation of the count is as follows:

	For	Scattering	Not Voting	Defective	Total
For President One Year					
T. D. Lynch	858	7	0	17	882
For 2nd Vice President Two Years					
W. S. Bidle	864	1	0	17	882
For Secretary Two Years					
W. H. Eisenman	864	1	0	17	882
For Director Two Years					
S. M. Havens	861	3	1	17	882

Respectfully submitted,
Committee of Tellers

L. S. COPE,
C. W. SIMPSON,
C. G. SHONTZ, Chairman

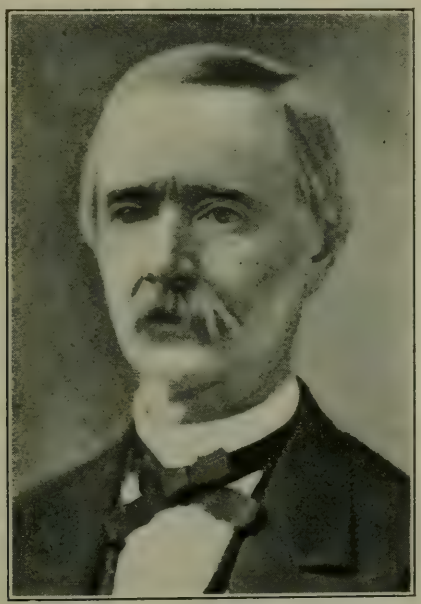
VOLUME TWO TRANSACTIONS INDEX READY

THE index for Volume Two TRANSACTIONS is now ready for distribution. All those who desire a copy of this index may obtain it by addressing their request to W. H. Eisenman, National Secretary, 4600 Prospect Ave., Cleveland.

WILLIAM KELLY

THE following sketch of William Kelly's life and of his claims to the first conception of the pneumatic process for steel making are reproduced here in a slightly abridged form from a very interesting article, "The Romance of Steel and Iron in America," by Herbert N. Casson, in Munsey's Magazine for April 1906.

In 1846 William Kelly and his brother bought the Suwanee Iron Works, near Eddyville, Kentucky. Kelly's father was a well-to-do landowner in Pittsburgh, where it is said that he erected the first two brick houses in the city. At the time when William Kelly began to make iron he was thirty-six years old, a tall, well-set-up, muscular, energetic man, with blue eyes and close-cropped beard. In inventiveness his brain



WILLIAM KELLY

ranked high; in business ability, low. He had left a commission business and become an iron maker mainly to carry out a process which he had invented, by which larger sugar kettles were to be made. The "Kelly kettles" became well known among the Southern farmers.

He had married Miss Mildred A. Gracy, of Eddyville, and secured the financial backing of his wealthy father-in-law. His iron plant was a fairly good one, close to high-grade ore, and needing the work of about three hundred negro slaves. Mr. Kelly was strongly opposed to slavery, and tried to escape from being a slaveholder by importing Chinese. He was the first employer in this country to make this experiment, and found it successful; but international complications prevented him from putting it into practice on a larger scale.

Kelly's first aim was to make good wrought iron for his Kettles

and for customers in Cincinnati. His iron was refined in what was called a "finery fire,"—a slow, old-fashioned process which used up quantities of charcoal.

In a year all the wood near the furnace had been burned, and the nearest available source of supply was seven miles distant—a fact with which the unbusinesslike Kelly had not reckoned. To cart his charcoal seven miles meant bankruptcy, unless—he could invent a way to save fuel.

One day he was sitting in front of the "finery fire" when he suddenly sprang to his feet with a shout, and rushed to the furnace. At one edge he saw a white-hot spot in the yellow mass of molten metal. The iron at this spot was incandescent. It was almost gaseous. Yet there was no charcoal—nothing but the steady blast of air. Why didn't the air chill the metal? Every iron maker since Tubal-Cain had believed that carbon and oxygen had an affinity for each other. They knew what air was and what iron was, and like a flash the idea leaped into his excited brain—**there is no need of charcoal; air alone is fuel.**

It was as simple as breathing and very similar, but no human mind had thought of it before. When the air is blown into the molten metal the oxygen unites with the impurities of the iron and leaves the pure iron behind. Oxygen—that mysterious element which gives life to all creatures, yet which burns up and destroys all things; oxygen, which may be had without money in infinite quantities—was now to become the creator of cheap steel.

Kelly was carried away by the magnitude of his idea. His unrestrained delight, after months of depression, amazed every one in the little hamlet. Most of his neighbors thought him crazy. Only three listened with interest and sympathy—two English iron workers and the village doctor.

At first Kelly snapped his fingers at opposition. "I'll prove it publicly," he said. At his invitation a number of jesting iron makers from Western Kentucky gathered around his furnace the following week, and Kelly, caring nothing for patents, explained his idea and gave a demonstration of it. Air was blown through some melted pig iron, agitating it into a white heat, to the amazement of the brawny onlookers. A blacksmith seized a piece of the refined iron, cooled it, and with his hammer produced in twenty minutes a perfect horseshoe. He flung it at the feet of the iron-men, who could not believe their eyesight, and seizing a second scrap of iron, made nails and fastened the shoe to the foot of a nearby horse. Pig iron, which cannot be hammered into anything, had been changed into malleable iron, or something very much like it, without the use of an ounce of fuel.

Surely, the thing was too absurd. Seeing was not believing. "Some crank'll be burnin' ice next," said one. The iron-men shook their heads and went home to boast in after years that they had seen the first public production of "Bessemer" steel in the world.

Kelly called his invention the "pneumatic process," but it became locally known as "Kelly's air-boiling process." He proceeded at once to refine his iron by this method. He sent his steel, or refined iron, or whatever it was, to Cincinnati, and no flaws were found in it. Years before Mr. Bessemer had made any experiments with iron there were

steamboats on the Ohio River with boilers made of iron that had been refined by Kelly's process.

But now came a form of opposition that Kelly could not defy. His father-in-law said: "Quit this foolishness or repay the capital I have advanced." His Cincinnati customers wrote: "We understand that you have adopted a new-fangled way of refining your iron. Is this so? We want our iron made in the regular way or not at all."

About the same time Kelly's ore gave out. New mines had to be dug. Instead of making ten tons a day, he made two.

He surrendered. He became outwardly a level-headed, practical, conservative iron maker and won back the confidence of his partners and customers. Then one night he took his "pneumatic process" machinery three miles back into a secluded part of the forest and set it up. Like Galileo, he said: "Nevertheless, air is fuel!" No one knew of this secret spot except the two English iron-workers whom he brought out frequently to help him.

Under such conditions progress was slow. By 1851 his first converter was built—a square, brick structure, four feet high, with a cylindrical chamber. The bottom was perforated for the blast. He would first turn on the blast and then put in melted pig iron with a ladle. About three times out of five he succeeded. The greatest difficulty was to have the blast strong enough, otherwise the iron flowed through the airholes and clogged them up.

His second converter was made with holes in the side, and worked better. He discovered that he could do ninety minutes work in ten, and save further expense in fuel. One improvement followed another. In all he built seven converters in his backwoods hiding place.

In 1856 Kelly was told that Henry Bessemer, an Englishman, had taken out a United States patent for the "pneumatic process." This aroused Kelly's national pride more than his desire for a monopoly, and he at once filed in the Patent Office his claims to priority of invention. The Patent Office was convinced and granted him United States Patent No. 17,628, declaring him to have been the original inventor.

Then came the panic of 1857, and Kelly was one of the thousands who topped over into bankruptcy. To get some ready money, he sold his patent to his father for a thousand dollars. Not long afterwards, the elder Kelly died and willed his rights to his daughters, who were shrewd, businesslike women. They regarded their brother William as a child in financial matters and refused to give him his patent. After several years of unjustifiable delay, they transferred it to Kelly's children. And so, between his relations and his creditors, Kelly was brought to a standstill.

But even at the lowest point of defeat and poverty, he persevered. Without wasting a day in self-pity, he went at once to the Cambria Iron Works, at Johnstown, Pa., and secured permission from Daniel J. Morrell, the general superintendent, to make experiments there.

"I'll give you that corner of the yard and young Geer here to help you," said Morrell.

In a short time Kelly had built his eighth converter,—the first that really deserved the name,—and was ready to make a public demonstration. About two hundred shopmen gathered around his queer-looking apparatus. Many of them were puddlers, whose occupation would be gone if Kelly succeeded. It is often fear that makes men scoff, and the

puddlers were invariably the loudest in ridiculing the "Irish crank."

"I want the strongest blast you can blow," said Kelly to Leibfreit, the old German engineer.

"All right," answered Leibfreit. "I gif you blenty!"

Partly to oblige and partly for a joke, Leibfreit goaded his blowing engine to do its best, hung a weight on the safety-valve, and blew such a blast that the whole contents of the converter went flying out in a tornado of sparks. This spectacular display filled the hundred shopmen with delight. For days you could hear in all parts of the works roars of laughter at "Kelly's firewirks." In fact, it was ten years' joke in the iron trade.

In a few days Kelly was ready for a second trial, this time with less blast. The process lasted more than half an hour and was thoroughly unique. To every practical iron maker, it was the height of absurdity. Kelly stood coatless and absorbed beside his converter, an anvil by his side and a small hammer in his hand. When the sparks began to fly, he ran here and there, picking them up and hammering them upon his anvil. For half an hour every spark crumbled under the blow. Then came one that flattened out, like dough—proving that the impurities had blown out. Immediately he tilted the converter and poured out the contents. Taking a small piece, he cooled it and hammered it into a thin plate on his anvil, proving that it was not cast iron.

He had once more shown that cold air does not chill molten iron, but refines it with amazing rapidity if blown through it for the proper length of time. His process was not complete, as we shall see later, but subsequent improvements were comparatively easy to make. Bessemer, by his own ecorts, did not get any better "steel" in 1855 than Kelly had made in 1847.

For this exact account of Kelly's achievements I am indebted to Mr. J. H. Geer, who was his helper at Johnstown, and to others who were eye-witnesses of his earlier success in western Kentucky.

As early as 1861 Capt. E. B. Ward, of Detroit, and Z. S. Durfee, of New Bedford, obtained control of the patents of William Kelly, who had previously successfully experimented with the pneumatic process at Eddyville, where he owned the Eddyville Iron Works. In 1861 Mr. Durfee went to Europe to study the Bessemer process. During his absence Captain Ward invited William F. Durfee, also of New Bedford, and a cousin of Z. S. Durfee, to erect an experimental plant at Wyandotte, Mich., for the manufacture of pneumatic steel, and this work was undertaken in the latter half of 1862.

In May, 1863, Daniel J. Morrell, of Johnstown, and William M. Lyon and James Park, Jr., of Pittsburgh, having become partners of Captain Ward and Z. S. Durfee in the control of the patents of Mr. Kelly, the Kelly Pneumatic Process Company was organized, Mr. Kelly retaining an interest in any profits which might accrue to the company. It was resolved to complete the experimental works already undertaken and also to acquire the patent in this country of Mr. Mushet for the use of spiegeleisen as a recarburizing agent. This patent was granted in England in 1856 and in this country in 1857. Mr. Z. S. Durfee accordingly went to England to procure an assignment of Mr. Mushet's patent. The latter purpose was effected on the 24th of October, 1864, upon terms which admitted Mr. Mushet, Thomas D. Clare and John N. Brown of

England, to membership in the Kelly Process Company. On September 5, 1865, the company was further enlarged by the admission to membership of Charles P. Chouteau, James Harrison and Felix Valle, all of St. Louis. In September, 1864, William F. Durfee succeeded in making Bessemer steel at the experimental works at Wyandotte. This was the first Bessemer steel made in the United States.

Kelly remained at Jownstown for five years. By this time he had conquered. His patent was restored to him, and Mr. Morrell and others bought a controlling interest in it. He was now honored and awarded. The "crank" suddenly became a recognized genius. By 1870 he had received thirty thousand dollars in royalties; and after his patent was renewed he received about four hundred and fifty thousand more. After his process had been improved and widely adopted, Kelly spent no time claiming the credit or basking in the glory of his success. No man was ever more undaunted in failure and more modest in victory. He at once gave all his attention to manufacturing high-grade axes in Louisville, and founded a business which is today being carried on at Charleston, West Virginia, by his sons.

When more than seventy years of age, he retired and spent his last days at Louisville. Few who saw the quiet, pleasant-faced old gentleman in his daily walks knew who he was or what he had accomplished. Yet, in 1888, when he died, it was largely by reason of his process that the United States had become the supreme steel-making nation in the world. He was buried in the Louisville cemetery.

Th new process was perfected by a third inventor, Robert F. Mushet, a Scotchman. He solved a problem which had baffled both Kelly and Bessemer—how to leave just enough molten metal to harden it into the required quantity of steel. Instead of frantically endeavoring to stop the process at exactly the right moment, Mushet asked:

"Why not first burn out all the carbon, and then pour back the exact quantity that you need?"

This too, was a simple device, but no one had thought of it before. Since then other improvements have been added by Holley, W. R. Jones, Reese, Gilchrist and Thomas.

The new metal was soon called by the name of "Bessemer steel." Strictly speaking, it was not steel in the original use of the word. It was a new substance, very much like wrought iron. It was not hard enough to serve for all purposes. For knives, for springs, for hammers, for a thousand finer uses, steel must still be made by slower and more careful methods. The Bessemer product does the rougher work, where quantity and cheapness are essential. In an axe, for instance, the cutting edge is made of crucible steel and the rest of Bessemer steel. All the steel rails, the great beams and girders that make our skyscrapers and bridges, the plates of steamships, the wire, nails, tubes, freight-cars and innumerable things, great and small, are made of the new metal that was first produced less than sixty years ago.

It is probable that one reason for the naming of Bessemer steel was the fact that true steel was then selling at three hundred dollars a ton. The new metal might have been less highly esteemed had it been announced merely as a modified form of iron.

In 1870, both Kelly and Bessemer applied to the United States Patent Office to have their patents renewed. The Commissioner of

Patents refused to extend Bessemer's, stating that he had no right to a patent in the first place, but Kelly's was extended for seven years, on the ground that he had not yet received sufficient remuneration for his invention. As soon as it was known that Kelly's patent was to be renewed the Patent Office was fairly mobbed by objectors. Never before had there been such opposition to the renewal of a patent. The steel makers and the railroad men united in a chorus of protest. The dread of paying higher royalties drove them to attack Kelly's claims. Bessemer, whose right to royalties was now at an end, was lauded as the original inventor, while Kelly was vilified as an interloper. Out of this opposition sprang the exaltation of Bessemer and the belittling of Kelly, which deprived America of the credit for one of the world's greatest inventions.

Kelly's claim is supported not only by the United States Patent Office but by the most eminent authorities. "Kelly in America, Bessemer, Mushet and Goransson in Europe, discovered and developed the pneumatic process of treating pig iron," says Robert W. Hunt, the veteran steel expert of Chicago. James Park, one of the Pittsburgh "fathers of steel," declared that "The world will some day learn the truth and in ages to come a wreath of fame will crown William Kelly, the true inventor of the Bessemer process." Even an English writer, Zerah Colburn records that "the first experiments in conversion of melted cast iron into malleable steel were made in 1847 by William Kelly." And the greatest living authority on the history of American iron and steel—James M. Swank, who has been the secretary of the American Iron and Steel Association for a generation—says:

"Mr. Kelly claims the discovery of the pneumatic principle of the Bessemer process several years before it dawned upon the mind of Mr. Bessemer, and the validity of this claim cannot be impeached."

And so Henry Bessemer, who was second in the race, received ten million dollars, world-wide fame and knighthood; while William Kelly, who was first, received half a million dollars and comparative oblivion Kelly was not to any degree embittered by his country's disregard of him. He had an unwavering conviction that everything would he made right. Shortly before his death he said to his children:

"The day will come when some one will do me justice."

It remained for the Detroit Chapter of the American Society for Steel Treating to commemorate the achievement of the early pioneers in the development of the process that caused the United States to become the supreme steel making nation in the world.

DURALUMIN
A DIGEST OF INFORMATION

By Horace C. Knerr

Abstract of Paper

An alloy as light as aluminum but as strong as mild steel, equal in strength to high grade alloy steel of the same structural weight, ductile, resistant to corrosion, suitable for a large variety of manufacturing purposes, easily drawn, machined, and forged, taking a high polish, and which derives its remarkable properties from heat treatment, is one which must have the attention of physical metallurgists, designers and users of high grade metals of construction.

Duralumin is a comparatively new arrival in the field of metallurgy, but its interesting and valuable properties have earned for it so much publicity, that even the layman is familiar with the name and at least some of the characteristics of this remarkable aluminum alloy. Technical and popular papers on the subject have been numerous but scattered, with the latter not always entirely accurate. The aim of the present paper is to present in concise, but comprehensive form, the salient facts concerning duralumin. It includes discussions of composition, chemical and physical constitution, manufacture, casting, forging, heat treating mechanical properties, resistance to corrosion and industrial applications.

Every effort has been made for accuracy as well as brevity. Data have been compiled from a considerable number of references, from experiments conducted by the writer and from observation of the practical application of the material in the construction of aircraft of both the airship (lighter-than-air) and airplane (heavier-than-air) types. Compilation has been done under limitations as to time. The author will greatly appreciate the correction of any errors that may be noted.

Historical

THE behavior and properties of the alloy known as "duralumin" were first observed by Alfred Wilm during his investigations from 1903 to 1911, (12)* in the development of a material of construction for the Zeppelin airships. It was made at the Durener Metallwerks, Duren, Germany.

Aluminum rich alloys with magnesium and copper have become well known in Europe and America during the past twelve years under the name of "duralumin." (8).

Its manufacture was taken up by Vickers, Ltd., in England, prior to the war.

Manufacturer's using the name in the United States claim the sole right to do so under patents held by the Chemical Foundation, Inc.,

*Figures in parenthesis refer to sources of information, listed under Bibliography.

A paper presented at the Detroit Convention October 2-7. The author, is metallurgist, Naval Aircraft Factory, Philadelphia.

of N. Y. Products having almost the same composition and physical properties as the latter, but the subject of different patents, are manufactured under other trade names or symbols, such as "17S" and "Lynite 400". These alloys might perhaps be grouped under the broader term "duralumins".

The commercial manufacture of duralumin in the United States dates back to about 1919, however, rapid progress has been made and a product of excellent quality is now available. For convenience the term duralumin will be used thruout this paper, but the text applies as well to those alloys having substantially similar composition.

Composition

Compositions given for duralumin vary considerably, but the following limits are representative:—

Copper	3.5 to 4.4 %
Magnesium	0.2 to 0.75
Manganese	0.4 to 1.0
Aluminum (minimum)	92.00

Iron and silicon, as impurities, under 0.6% each.

A typical analysis is:—

Copper	Magnesium	Manganese	Iron	Silicon	Aluminum
3.90	.60	.50	.40	.25	94.35

Tin, lead, nickel, zinc, nil, or trace.

The composition is modified for special purposes. Where severe drawing or deformation is required, the copper content may be reduced and the manganese omitted entirely, giving a material of lower tensile strength but increased ductility. The addition of small quantities of chromium is said to improve the burnishing qualities.

Manufacture

The manufacture of duralumin includes the following steps:— (15)

1. Preparation of the alloy
2. Casting the ingot
3. Hot rolling or cogging into blooms, billets or slabs
4. Hot or cold rolling to sheet, strip, bar, etc.
5. Heat treating (and ageing)
6. (Sometimes) Working to special shape while plastic, immediately after quenching, before ageing
7. (Sometimes) Cold working, after heat treatment and ageing, to increase hardness and strength.

Casting the Ingots

Details of manufacture are difficult to obtain, but the practice may be described briefly as follows:

The constituents are melted in an iron crucible, beginning with aluminum ingot of 99 per cent purity, adding 50:50 copper-aluminum alloy for the copper, a 90:10 aluminum-manganese alloy for the manganese, and finally, just before pouring, a 90:10 aluminum-magnesium alloy for the magnesium. Adding straight magnesium in lumps in the ladle, just before pouring, has also been recommended.

Melting and pouring are done at the lowest possible temperatures, 1275-1330° F. (690-710° C.) has been given for the latter. An iron ladle

is used, externally insulated to retain the heat. The metal is poured very slowly into iron molds, permitting solidification to progress from the bottom upward, while pouring, so that only the top layer of metal is liquid. This minimizes shrinkage cavities, porousness and segregations. There is only about 5 per cent head. The ingots are brick-shaped and weigh 50 to 75 pounds.

Sheet, Strip and Channels

Duralumin is used principally in sheet form, or products derived from sheet. The ingots are reheated to about 840° F. (450° C.) for rolling, the furnace temperature being about 900° F. (480° C.) Overheating must be avoided, as the metal is hot short. Rolls should be warmed to remove chill and are lubricated in the ordinary manner. Ingots are rolled to slabs ⅜ to ¼ inch thick at the first rolling, and later cold rolled to finished gage. There should be only slight cracking at the edges. The sheets may be annealed two or three times during cold rolling. Sheets which are required in the heat treated condition are generally given one or more passes through the rolls (cold) to flatten them after quenching. Sheets may be slit into strips for the production of profile shapes, such as channels, etc. These strips are coiled, quenched, straightened, immediately rolled to the desired section and then allowed to age.

Bar Stock, Rod, Wire and Tube

Bar stock, rod and wire are also used in quantity; rivets being made from the latter. Bars up to 2½ inches in diameter are made by extrusion, the process being similar to that used for brass. Bars are also forged, especially above 2½ inches in diameter. (6) Heavy angle and other sections are extruded. Seamless tubing has been produced to a considerable extent in Germany and England, but its production in this country is just beginning. The oblique rolling method of making seamless tube blanks is not successful with duralumin. Blanks and heavy tubes are produced by extrusion, and thin walled tubes by solid drawing. For extrusion, ingots are about 6 inches in diameter by 12 inches long. The temperature is approximately 950° F. (510° C.).

Cold working duralumin which has been heat treated and aged has much the same effect as cold working steel, increasing the hardness and tensile strength at the expense of ductility.

Remelting Scrap

Duralumin scrap when properly remelted and forged will have properties nearly if not quite, as good as the original metal. Cast iron or steel crucible is used. Gas, oil, coke or electric heat may be used, but furnace gases should be excluded from the crucible. The scrap is heated to a plastic state and kneaded well with an iron rod. When all is plastic, the temperature is raised to between 1290-1380° F. (700-750° C.) held for a few minutes, stirred, skimmed, allowed to stand for about one minute and casted. Before the first skim, a little zinc chloride (1 ounce to 50 pounds of scrap) should be stirred in as a flux. Temperatures should be held as low as possible, and the metal should not be kept hot longer than necessary.

Ingots should be cast in iron molds, as described under "manu-

facture" and the molds should not be larger than necessary. The ingots should be heated to about 660° F. (350° C.) and forged with light blows into bars, as outlined under forging.

Forging

Duralumin makes excellent plain or die forgings. (20) (6) (16) Forging temperatures are given from 660-840° F. (350-450° C.) by various authorities. This is below the color range and pyrometric control is essential. Heating may be done in a salt bath, or in a muffle or semi-muffle furnace. Contact with an open flame damages the metal. Overheating causes brittleness, as the metal is hot short above 840 degrees Fahr.

Billets are heated much more rapidly and probably more uniformly in the salt bath than in a muffle furnace. A film of salt will adhere when the parts are withdrawn, but will not, as a rule, interfere with the forging. It may be removed by a quick rinse in hot water. Forgings may become overheated and crack, due to too severe working. Light blows and gradual reductions are preferable. The use of a small belt driven drop hammer has been recommended. About the same amount of power is required as in forging steel, and similar dies are used. When the metal becomes cold it gives a decided metallic ring.

Castings

Duralumin is not used for castings. It has a persistent tendency to porosity, and its physical properties, although improved by heat treatment, are inferior to other high grade aluminum casting alloys. The properties of cast duralumin are given by Grard (10) as follows:—

	Tensile strength pounds per square inch
Sand cast	15,600
Sand cast and quenched	19,900
Chill cast	14,200
Chill cast and quenched	21,300

Elongation and shock resistance is approximately zero in all cases. The superior properties of duralumin are obtained only from the worked material.

Heat Treatment

Duralumin bears the same relation to aluminum that high-strength alloy steel bears to soft iron or mild steel, and similarly, its superior qualities depend upon proper heat treatment. The behavior of duralumin under heat treatment is in outward appearance, strikingly different from that of steel, although fundamentally, it is in many ways similar, as will be discussed under (Theory of Heat Treatment.)

Heat treatment consists simply in heating to about 932 degrees Fahr. holding until saturated and quenching. This must be followed by a period of "ageing" at room temperature. Immediately after quenching, duralumin is soft. Its hardness and tensile strength then increase, at first rapidly, and then slowly for a period of 4 to 10 days, when it has attained its maximum strength and hardness. Duralumin softens greatly when heated to the quenching temperature, and should therefore be properly supported in the furnace, and handled with care in quenching, to avoid deformation. However, on account of its soft

condition immediately after quenching, it may easily be straightened at this time, should deformation occur. Heat treatment, to produce maximum physical properties, is sometimes called "tempering" to distinguish it from the process of annealing. (See Annealing)

Heating

Heating may be done in an electric, gas, oil or even coal fired muffle or semi-muffle furnace provided proper temperature control and uniformity are assured. Contact with an open flame damages the metal. A salt bath composed of a mixture of approximately equal parts of sodium nitrate and potassium nitrate is the most approved method of heating because of the temperature uniformity, and the rapidity with which the parts are heated. A thin layer of the salts will adhere to parts when they are withdrawn, but this is quickly washed off when quenched in water, especially in hot water. It is important that the salt be entirely removed from the metal to avoid subsequent corrosion. A tank made

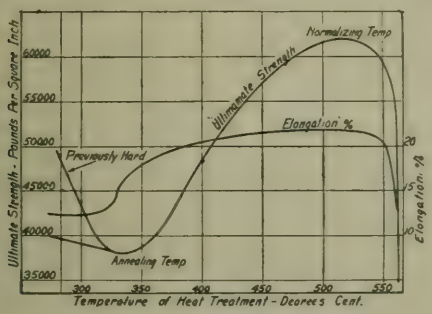


Fig. 1—Variation in strength of Duralumin with the Temperature of Heat Treatment. (After Vickers, Ref. 6.)

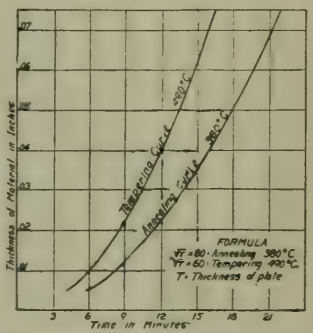


Fig. 2—Curves for annealing and tempering Duralumin for plates of various thickness, giving the time allowance in the salt bath.

of boiler plate; welded or riveted and caulked at joints, heated by gas or oil flame is suitable for the salt bath. (Carbonaceous fuels, such as coke, and charcoal, should never be used in heating the salt bath, as leakage or spilling of the nitrates into this fuel will cause violent combustion or explosion). The same nitrate bath may be used at the lower temperatures required for annealing. The furnace or salt bath may be at the specified maximum quenching or annealing temperature, but not higher, when the work is inserted. Preheating is not required.

No scale is produced in heating duralumin, either in the furnace or salt bath, although a slight discoloration occurs, which is purely superficial.

Quenching Temperature

The physical properties obtained by heat treatment improve with higher quenching temperature up to about 986° F. (530° C.) Heating above 1004° F. (540° C.) causes rapid deterioration. (See Theory of Heat Treatment). For commercial purposes, the limits 915-950° F (490-510° C.) are generally used; 930-970° F. (500-520° C.) may be used if very close regulation is assured. Accurate pyrometric control is essential.

Base metal couples may be inserted in the bath, with or without a thin steel tube sheath. The variation of tensile strength and elongation with quenching temperature are shown in Fig. 1. (6).

Time of Heating

The time of heating, or "soaking", must be sufficient to insure that the work has come to the desired temperature throughout. Additional soaking is not harmful, except that thin sections are likely to blister if left too long in the nitrate bath. Parts will heat more rapidly in the bath than in the furnace. The time in the salt bath for various sections is, roughly as follows:—

Rivets, thin sheet and strip.....10 to 15 minutes
Bars and thick sections.....30 minutes to 1 hour
Heavy forgings and bars.....2 hours

Vickers (6) give the following formulas for the minimum time in minutes in the *salt bath*:

For heat treating..60 times square root of diameter or thickness in inches
For annealing.....80 times square root of diameter or thickness in inches

This works out for sheet as shown in the curves, Fig. 2. The time required for heating in an electric muffle furnace is much longer than in the salt bath. A definite rule is not at the moment available, but the results of the following tests are instructive:

(a) Specimens of sheet duralumin 1/16 and ⅛ inch thick, heated in an electric muffle furnace for 20 minutes showed very slightly lower tensile properties than specimens of similar material heated for the same period in a nitrate bath, the temperature in both cases being 932 degrees Fahr. This indicates that 20 minutes is a minimum time for heating material of this thickness in a furnace; 35 to 40 minutes would be a safer allowance, with a proportionately longer time for thicker parts.

(b) A duralumin ingot 2¼ inches in diameter and 11 inches long having an axial hole ¾ inch in diameter and 8 inches deep into which a thermocouple was inserted, was heated in an electric muffle furnace and in a nitrate bath, to determine the time required to heat from room temperature to the maximum in each case. The heating curves are shown in Fig. 3. The core of the ingot reached the temperature of the bath (875 degrees Fahr.) in approximately 15 minutes; whereas it was still 50 degrees Fahr. below the furnace temperature (830 degrees Fahr.) after 90 minutes; a ratio of 6 to 1. It is evident that the metal absorbs heat much faster from the liquid salt than from the air.

Quenching

Water is generally used as a quenching medium, and is practically essential when the salt bath is used in heating, in order to dissolve the adhering salts. Quenching in boiling water is generally recommended as it is believed to give the best physical properties after ageing and it is less likely to cause distortion or cracking, due to cooling stresses than cold water. Violent spattering occurs when parts are quenched in boiling water.

Quenching in cold water, that is, at room temperature, (about 60 degrees Fahr.), leaves the material in a softer and more easily work-

able condition, and experience has shown that the physical properties are little if any, inferior to those obtained by quenching in boiling water. There is also some evidence that resistance to corrosion is improved by quenching in cold water (See Corrosion). Ordinary light quenching oil is a satisfactory quenching medium when a furnace is used in heating. In some cases the same equipment used in heat treating steel can therefore be used for duralumin. In heat treatment, the parts should be quenched immediately after removal from the furnace, with minimum loss of temperature. An increase of the temperature of the quenching bath up to 300° F.(150° C.) is said to give a slight improvement in tensile properties, but there is no further improvement up to 395° F. (200° C.) while higher temperatures are detrimental. (1)

Various Quenching Mediums

Experiments were carried out (20) to determine the tensile properties produced in duralumin sheet by quenching in various mediums, including air cooling. Tensile speciments 1/16 and 1/8 inch thick

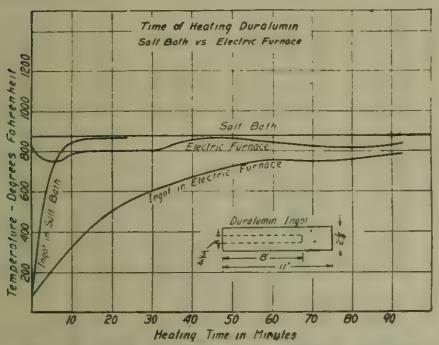


Fig. 3—Time of Heating Duralumin Salt bath versus Electric furnace. Salt bath tank, 4 feet 3 inches by 18 inches by 21 inches. Hoskins muffle furnace 5 inches by 7 inches by 14 inches.

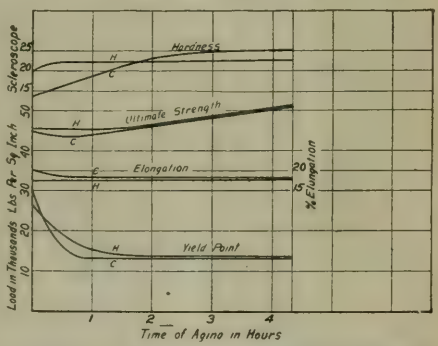


Fig. 4—Variation in mechanical properties with time after quenching in hot and cold water. 1/8-inch duralumin sheet held 20 minutes in nitrate bath at 932 degrees Fahr.

were used, care being taken to insure uniformity of material. These were heated to 930 degrees Fahr. in an electric muffle furnace and quenched in cold water (60 degrees Fahr.) boiling water, quenching oil, still air, and in the direct blast of a 12-inch electric fan. Hardness and tensile tests are summarized in Table I.

The tensile properties obtained from the various mediums differ little, and practically all meet the specifications. Very slow cooling (as in the furnace) from the quenching temperature anneals duralumin. The cooling of the tensile specimens in air was evidently sufficiently rapid to produce the effects of heat treatment. Larger parts would cool more slowly and would doubtless have correspondingly lower tensile properties.

The scleroscope hardness readings indicate the progress of ageing. A comparison of the hardness produced immediately (5 minutes) after quenching is interesting. Cold water gave the softest, most workable, material, and boiling water the hardest. The ultimate hardness was nearly the same, for each thickness. The specimens were allowed to remain in the boiling water for one minute. Cold water is shown to

be the most desirable medium where severe cold working is to be done. The effect of the quenching medium on the resistance to corrosion was very pronounced (20) and is discussed under Corrosion.

Ageing

Ageing after quenching proceeds normally at ordinary room temperature, 70 degrees Fahr., and will be practically complete in four days, although there is a slight improvement for about six additional days. Ageing is accelerated with increase of ageing temperature up to about

Table I

Quenching Mediums.

Tensile tests (aged 10 days)

Quenching medium	Scleroscope hardness after: — 5 minutes	2 days	5 days	Yield point pounds per square inch	Ultimate strength pounds per square inch	—Elong.— % 2 inches	% 4 inches
Specimens 1/6-inch Thick							
Cold water, 60 degrees Fahr.	14.4	26.6	26.8	36,560	61,640	18.9	16.6
Boiling water	20.8	25.4	26.2	35,640	61,500	19.1	17.6
Oil (Houghton's)	16.4	26.0	27.0	35,300	61,400	18.9	17.3
Air blast	18.0	26.0	27.0	35,560	59,330	18.0	15.4
Still air	18.0	25.0	26.0	33,000	58,900	18.3	16.0
Specimens ⅛-inch Thick							
Cold water	15.2	29.6	29.6	38,700	61,000	19.2	16.9
Boiling water	23.0	27.4	28.0	35,900	61,740	19.8	17.2
Oil (Houghton's)	19.4	28.4	28.6	38,300	61,700	19.8	15.7
Air blast	19.0	27.0	28.0	34,250	58,580	17.5	16.0
Still air	20.0	26.0	27.0	36,200	58,050	18.0	15.0

Tensile Test Requirements

Yield stress	25,000 pounds per square inch minimum
Ultimate stress	55,000 pounds per square inch minimum
Elong. in 2 inches	18% minimum

300 degrees Fahr. but above that temperature, the physical properties are impaired. Heating to 212 degrees Fahr. for several hours is about as effective as several days of ageing at room temperature. This is easily accomplished by allowing the material to remain in the boiling water in which it is quenched. Changes of physical properties with time of ageing are shown in Figs. 4 and 5.

Annealing

Duralumin is annealed by heating to between 660 and 715 degrees Fahr. followed by quenching or by cooling in air or in the furnace. This leaves the material in a soft and workable condition, even softer than when freshly tempered and unaged. The annealed material when furnace cooled will remain soft indefinitely, or harden only slightly when more rapidly cooled, so that the necessity for immediate working, as after tempering, is avoided. Severe cold working will cause hardening, as in other metals, but this is removed by re-annealing, which may be repeated a number of times without ill effects. Annealed material must finally be heat treated (tempered) to give it the required high

tensile properties. Soaking at the annealing temperature and slow cooling are essential to obtain the softest metal. Annealing may also be accomplished by very slow cooling from the quenching temperature.

Properties

General

Duralumin has now been in use abroad for approximately a decade. During this time the reliability and permanence of its properties as a material of construction have become quite well established. The peculiar behavior of duralumin in hardening after heat treatment, gave rise, when the metal was first introduced to some doubt as to the permanence and stability of the material in the hardened condition. Tests on samples of the material which had been exposed in the open for about eight years showed the same strength as obtained within a week after heat treatment. (6) Table II shows some interesting properties of duralumin.

Either in the ingot (chill cast) or as rolled or forged duralumin has

Table II
Some Physical Constants of Interest

Specific gravity	2.80 to 2.85 (4)
Weight, pounds per cubic inch	.100 to .102
Weight, pounds per cubic foot	173 to 176
Melting range	1000-1200° F. (540-650°C.)
Cofficient of linear expansion, per degree Cent	.0000226 (4) (6)
Thermal conductivity (silver 100)	31
Specific heat	.214 (6)
Electrical resistivity (12)	
Annealed state	3.43 microhms per centimeter cube
Heat treated state	4.73 microhms per centimeter cube

Duralumin is non-magnetic.

a remarkably clear, silvery tone when struck. Heat treated duralumin takes a fine polish, which is apparently permanent indoors and which does not tarnish in handling.

Duralumin siezes badly when in friction with itself. It seems to work well in bearing contact with brass, and has been used with success (15) as a bearing metal in contact with hardened steel. Threaded parts, such as bolts, fittings, etc., are best used in conjunction with another metal to avoid seizing. Lubricants help to some extent to prevent seizing, but their effect is soon destroyed in the presence of moisture, which causes corrosion, or gasoline and other solvents, which remove the lubricant.

Mechanical Properties

The following values shown in Table III are taken from technical data for duralumin sheet issued by an American manufacturer. (16)

These data apply to sheets up to 18 inches wide and ranging in thickness from .010 to .625 inch in the annealed or heat treated state and up to 14 inches wide and .016 to .125 inch thick in the hard rolled condition. The heat treated material can be bent 180 degrees over a mandrel four times the thickness of the sheet, and will withstand slight forming operations. The annealed material may be drawn; spun, stamped and formed into a variety of shapes, like brass and mild steel.

Heat treatment of annealed material gives it the same properties as listed under "Heat Treated". Either heat treated or hard rolled material may be annealed.

The hard rolled material is very hard, strong and springy and will not stand bending or forming. It machines and threads well. The strength of duralumin, is as in most metals, affected by the amount of working it has received, light sections, having a higher unit strength than thick ones. The thickness of the section also influences the results of heat treatment.

The following is a fair specification for sheet less than 0.2 inch thick:— (18)

Specifications:—
Heat Treated (Test 4 days after treatment)
Yield point, tension (min.)..... 25,000 pounds per square inch
Ultimate strength (min.)..... 55,000 pounds per square inch
Elongation in 2 inches (min.)..... 17 per cent
Specific gravity ..... 2.85 (max.)
Bend Test—In any direction must stand 180-degree bend over a diameter equal to four times the thickness of the sheet.
Annealed state (12 hours after treatment).
Ultimate tensile strength....25,000 to 38,000 pounds per square inch
Elongation in 2 inches (min.).....10 per cent

In sheet 0.2 inch thick or over, a safe minimum value of ultimate strength is 50,000 pounds per square inch, the other properties remaining about the same. For sheet of very light thickness, such as

Table III

Mechanical Properties of Sheet Duralumin Made by an American Producer

Condition	Heat treated (pounds per square inch)	Annealed (pounds per square inch)	Hard rolled (pounds per square inch)
Ult. tensile strength	55,000-62,000	25,000-35,000	67,000-72,000
Yield strength	30,000-36,000	.....	55,000-65,000
Elongation in 2 inches	18-25%	10-14%	3-8%
Brinell hardness	93-100	54-60	130-140
Scleroscope hardness	23-27	9-12	37-42

0.02 inch and under, a softer grade of material may be used, the tensile strength being 40,000 pounds per square inch or more, and the elongation about 15 per cent in 2 inches.

The properties of forgings follow those of sheet.

Like steel, the tensile properties of duralumin vary somewhat in transverse and longitudinal specimens taken from sheet. The longitudinal values (with the grain) are the more uniform, and show the higher ductility. Transverse tests show lower elongation and sometimes slightly higher tensile strength. This condition seems to depend largely on the practice used during manufacture; some sheets showing more nearly uniform transverse and longitudinal values than others.

The following are fair minimum values for tempered bar stock (hexagon, round, etc.) but may be improved upon:

Diameter	Tensile strength pounds per square inch	Elong. per cent in 2 inches
¼ to 1 inch	55,000	18
Over 1 to 1½ inches	50,000	18
Over 1½ inches	45,000	18

The dimensions of test speciments affect the results. Thin sheets give lower elongation values. Standard specimens must therefore, be agreed upon. Standard tensile specimens ½ inch in diameter with a 2-inch gage length, or of the same geometric proportions if of smaller diameter are used for bar stock. For sheet, 2-inch gage length ½ inch wide, is a tentative standard.

In general extruded duralumin is slightly lower in tensile strength than rolled or forged duralumin. Aside from this there seems to be little difference in properties.

Compression and Shear

The compressive strength of duralumin is about the same as the tensile strength. Following are the results of tests made on rolled and extruded rod, the specimens being 1 inch in diameter and 4 inches long. The extruded specimens were machined from a 2-inch diameter bar. The rolled bar was 1 inch in diameter. (4)

Compression Tests

Process	Condition	Yield point pounds per square inch	Ultimate strength pounds per square inch
Rolled	As rolled	36,000	51,000
Rolled	Tempered	25,000	56,800
Extruded	As extruded	22,000	48,000
Extruded	Tempered	25,000	58,000

Shear

Data scarce, but 27,000 to 30,000 pounds per square inch are accepted values for tempered material.

Wire

Tempered wire normally has:—

Tensile strength	60,000 to 65,000 pounds per square inch
Yield stress	30,000 to 35,000 pounds per square inch
Elongation in 2 inches	22 to 26 per cent

Cold drawn wire has been made with a tensile strength of 80,000 pounds per square inch. This is inferior in strength to piano or aviation wire of the same weight, but may have many practical uses.

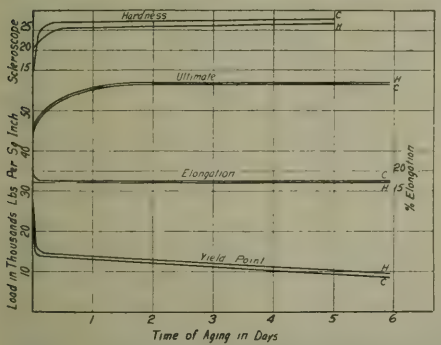


Fig. 5—Variation in mechanical properties with time after quenching in hot and cold water. $\frac{1}{16}$-inch duralumin sheet held 20 minutes in nitrate bath at 932 degrees Fahr.

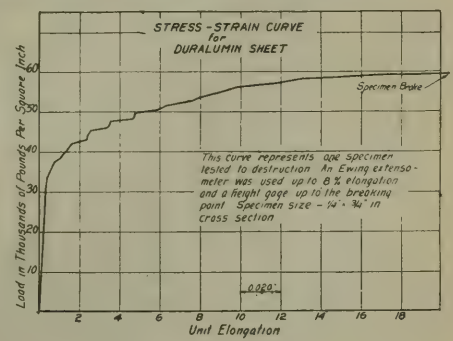

STRESS-STRAIN CURVE for DURALUMIN SHEET
Specimen Broke
This curve represents one specimen tested to destruction An Ewing extensometer was used up to 8% Elongation and a height gage up to the breaking point Specimen size - ¼" x ¾" in cross section
Load in Thousands of Pounds Per Square Inch
Unit Elongation

Fig. 6—Stress-strain curve for Duralumin Sheet. Specimen ¼ x ¾ inches cross-section.

Fatigue Endurance

Data on the fatigue endurance limits of duralumin are scarce. Endurance tests are underway at the Bureau of Standards and by vari-

ous manufacturers but results have not yet been published. The following is quoted from a German source:

"Duralumin when heat treated and cold worked to give about 6 per cent elongation in 2 inches corresponding to a yield point above 35,000 pounds per square inch, will withstand unlimited alternations of stress between 0 and 20,000 pounds per square inch tension." (13)

Experience, extending over a period of ten years or more in Europe has shown that the material is perfectly reliable when correctly used. Duralumin should not be used in thin sections where it will be subject to severe vibration while under stress, as at the joints of structural members in airplanes. At these locations it has been the German practice to re-enforce the joint with mild steel, attached to the duralumin members by rivets. Correct heat treatment and freedom from flaws and sharp reentrant angles are of course essential, as in all metals of construction. The following abstract from a paper by Rollason (23) is of particular interest:—

"The fatigue of the metal is indeed favorable. A sample connecting rod made for a standard passenger car was run in a special machine consisting of a motor-driven crank and weighted crosshead. The speed was about 1500 revolutions per minute and the load on the crosshead would correspond with about 50 per cent overload on the motor. The duralumin rod gave a life of 353 hours and was still functioning when a casting on the crosshead failed in fatigue. A standard drop-forged steel rod for the same car showed a life of only 25 hours under the same conditions, for example, with 50 per cent overload and another between 40 and 50 hours at normal load both the steel rods failing in fatigue at the big end. The steel rod was of smaller section, but about double the weight of the forged duralumin rod. Some of these rods also have stood up well in block and road tests in the motor to the extent of over 10,000 miles of running. A notable feature of a number of these tests has been that at the big end bearing, the rod has been run direct on the crankshaft without any bushing whatsoever. Forged and heat-treated duralumin, in fact, is showing up as a very satisfactory bearing material when the wear is against a sufficiently hard shaft. Rods have been run against both case-hardened and heat-treated shafts. Owing to the relatively high expansion of the aluminum alloys, however, it has been found necessary to allow a little more end play at the big end bearings than is standard practice with steel rods."

False Yield Points

Careful stress-strain tests show the appearance of several "false yield points," as illustrated in Fig. 6. If the load is removed and then reapplied, the lower yield points are eliminated. This characteristic may be regarded as an advantage for structural purposes, permitting the parts to adjust themselves to imperfectly distributed loads. These false yield points seem to be a peculiarity of the material in cold working. Both freshly quenched and aged specimens show this behavior. In testing freshly quenched specimens of sheet a distinct crackling sound was noted during pulling which seemed to be due to sudden yields occurring at various points, followed by hardening

at those points and transferring of the yield to some other point in the specimen. This action could be seen and felt.

Influence of Heat and Cold

Heat has an important influence on the strength (13) of duralumin. When heated, the strength decreases 10 per cent for an increase in temperature of 212 degrees Fahr. above room temperature and about 20 per cent for an increase of 300 degrees Fahr. The loss in strength increases with the increase in temperature. The elongation increases on first heating to a hardly appreciable extent, while between 300 and 390 degrees Fahr. it decreases. At 480 degrees Fahr. the elongation becomes the same as at room temperature. With further heating the elongation increases with increase of temperature.

A graph by Cohn (12) showing the influence of heat on the tensile properties of duralumin is reproduced in Fig. 7. As opposed to the influence of heat on the mechanical properties of duralumin, its strength

Table IV
Influence of Cold on the Strength of Duralumin

Testing temperature	The bar was tested in	Tensile Tests: Limit stretch and strain	Ult. strength kg/mm²	Elongation %	Impact test work of breaking kg/mm²
+ 20° C	Air	24.0	42.5	21.9	2.6
0	Snow	23.6	43.0	21.8	2.6
— 20	Mixture of snow and table salt	24.0	43.7	23.1	2.7
— 40	Mixture of snow and calcium chloride	24.0	44.0	22.1	2.7
— 80	COz snow	25.2	44.4	22.7	2.7
—190	Liquid air	32.3	53.7	28.7	2.6
+ 20	Air	23.0	42.3	23.3	2.6

and elongation are somewhat increased by a decrease in temperature, the impact strength being practically unaffected. The results of some German tests at temperatures down to that of liquid air (310 degrees Fahr.) below zero are given in Table IV. (13).

Properties Compared with Steel and Aluminum

A comparison between some of the properties of duralumin, aluminum and steel is given in Table V. The strength weight factor or "strength-weight efficiency," obtained by dividing the tensile strength by the specific gravity (unit weight) of a material affords a very clear comparison between the value of materials for purposes where strength and lightness are of first importance. On this basis, duralumin is 17 per cent better than a good alloy steel, and nearly three times as good as mild steel or half hard aluminum, while its ductility is higher than that of the alloy steel, nearly as high as the mild steel, and nearly twice that of half hard aluminum. Its weight is only about 6 per cent greater than that of aluminum, but its strength is 3.0 times that of half-hard aluminum and 4.5 times that of soft aluminum. (12,000 pounds per square inch). Its unit weight is about 36 per cent that of steel, or roughly 1/3. The modulus of elasticity of duralumin is

practically the same as that of aluminum and about 1/3 that of steel. This, in relation to the area for a given strength makes duralumin about equivalent to steel as a long column or beam where failure occurs by flexure.

For light sections, duralumin has a great advantage over alloy steel as it is less subject to local or detail failure, being approximately three times as thick for the same strength and weight. Alloy steel sections of equal strength (theoretical) and weight, as those of thin duralumin, would fail by crinkling, and would be too thin to be practicable. The ease with which duralumin can be machined, forged, drawn, etc,. gives it a great advantage over its structural competitor, alloy steel, and offsets some of the difference in first cost, which is at present roughly 4 or 5 times that of alloy steel per pound. This is largely offset by the fact that about three times as much material is obtained as for an equal weight of steel.

Fabrication

Drawing, Forming, Etc.

The peculiar "ageing" property of duralumin, namely, its softness immediately after quenching, followed by gradual hardening and increase of strength at room temperature, is in some ways an advantage

Table V
Comparison of Properties—Duralumin-Aluminum-Steel

	Duralumin tempered	Aluminum half hard	Mild steel	Alloy steel
Specific gravity	2.85	2.7	7.8	7.8
Weight, lb./cu. in.	0.101	0.094	0.27	0.27
Wt. 1 sq. ft. 0.1" thick in pounds	1.44	1.35	3.90	3.90
Tensile strength, pounds per square inch	55,000	18,000	55,000	125,000
Yield point, pounds per square inch	25,000	.....	36,000	100,000
Elongation in 2 inches	17%	7%	20%	15%
Modulus of elasticity (millions)	9.4 to 10	9.8	30.	30.
Strength/weight factor, S/W	19,250	6,650	7,050	16,000
S/W compared, duralumin 100%	100	33.5	36.6	83
Section area for equal weight	1.00	1.05	0.36	0.36

in fabrication, as it permits severely working the metal just after heat treatment. Such work should be done within the first hour after quenching. Quenching in cold water gives greater softness and a longer period of working than in hot. Rivets are heat treated just before use. They are headed easily and then attain their full strength without further attention. Long channels and other sections may be produced by heat treating a coil of flat strip, then straightening and rolling it to shape immediately. The long straight members would be difficult to handle in heating and quenching if annealed material were used and heat treated after forming. Either heat treating or annealing may be repeated a number of times without ill effects. (Specimens of duralumin wire have been heat treated successively 20 times without appreciable change in physical properties.)

In general, if only *one* operation is required to finish a part, it may be quenched (heat treated) just before that operation. If several operations are required, annealing is preferable, tempering treatment being

given just before, or after the last operation. It is advisable in shops where duralumin is used in large quantities that all stock duralumin which is in the annealed condition shall be painted a distinguishing color. (Blue has been adopted in British practice.) Annealed or freshly quenched sheet duralumin may be formed and deep drawn to a considerable degree through somewhat less than soft aluminum. In bending soft material, a *minimum radius* is the thickness of the sheet, and for tempered material, twice the thickness. Annealed material must be finally heat treated to attain maximum tensile properties. Light sections and sheet in either the hard or soft state are conveniently cut on a metal cutting band saw.

Extrusion

Extrusion of light, as well as of heavy sections is practicable. Some tubes intended for use in the honeycomb type of radiator were

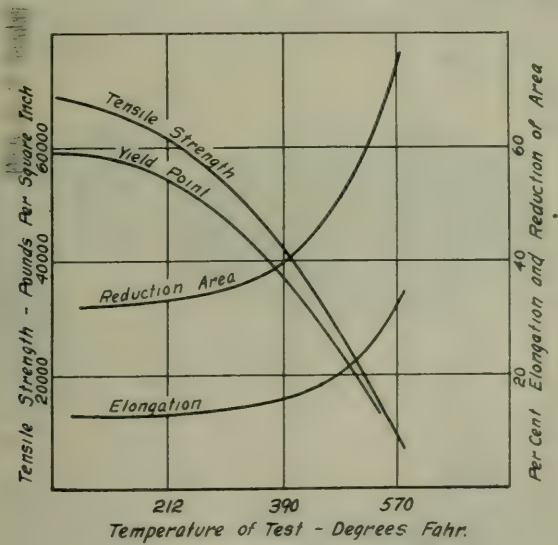


Fig. 7—Effect of Heat on Tensile properties. (After Cohn. Ref. 12.)

recently produced by an American manufacturer. These were 5 inches long, with an outside diameter of 0.26 inches and a wall thickness of 0.009 inches. The ends were expanded to a hexagonal shape for about ¼ inch.

Machining

The metal can be turned and machined at the same speed as brass and it does not seize or drag the tools like some aluminum alloys. It machines best in the tempered or hard rolled state. Kerosene has been found a good tool lubricant in machining and may be run smoking hot. British references (6) recommended paraffin oil, in threading and finishing. The metal threads well in the hardened state; but threaded parts are preferably used in conjunction with a different metal (brass

or steel) on account of the tendency of duralumin to seize or bind when in rubbing contact with itself.

Soldering

Duralumin may be soldered by the same means as aluminum, but the heat of soldering would tend to anneal heat treated material, and if heat treatment were done after soldering, the solder would be melted. In any case soldering is not recommended, as all known solders for aluminum rapidly deteriorate in the presence of moisture, so that the strength of the joint is completely lost. The action is due to electrolytic corrosion. (11) In soldering metal parts which are to come in contact with duralumin, great care should be taken to completely

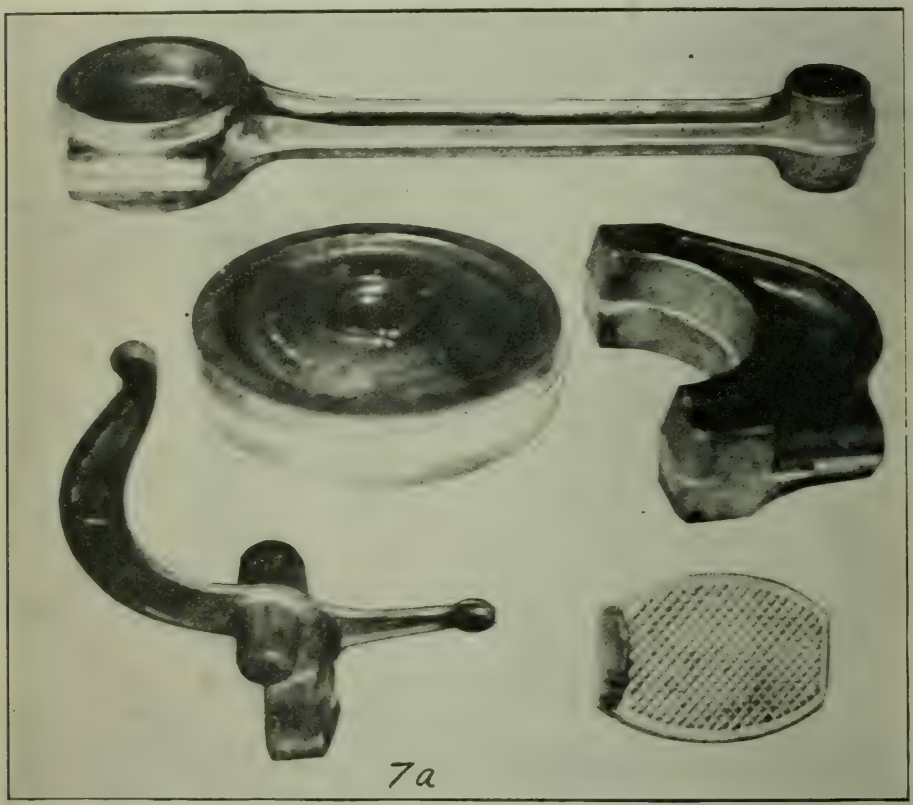


Fig. 7a—Small forgings manufactured from aluminum alloy. (Courtesy Aluminum Company of America.)

remove all traces of soldering flux containing corrosive materials, such as zinc chloride, etc., or better, to use a non-corrosive flux, such as resin, stearic acid, etc.

Welding

The welding of duralumin has heretofore been considered impracticable. Recent experiments (19) have shown that it may be welded in about the same manner as aluminum, except that more care and skill are required on account of greater tendency to melt, become

brittle or "burn," and buckle. Narrow strips sheared from the sheet were used for welding rod. Strong welds may be made by either the "butt" or the "flange" method. The flange method is preferable, as it produces a fillet on the under side of the weld, whereas the butt method is apt to leave a sharp reentrant angle there, which would tend to cause failure under vibration. Flange welds are easier to make than butt welds on thin sheets.

In making the butt type of weld the sheets to be joined are placed edge to edge and "tacked" together at intervals of about one inch by melting the edges together at those points and adding a little metal from the welding rod. Fresh flux is then applied and the weld made continuously by melting the edges together and building up the joint with metal from the welding rod. This type of weld is more successful with sheets of 16 BWG (0.065 inch) thickness, or thicker, than with lighter gage sheets, as the latter melt through very easily. In making the flange type of weld, the edges of the sheet to be joined are bent up at right angles, an amount equal to about three times the thickness of the sheet. These flanged edges are clamped together (conveniently done with small "C" clamps) and tack-welded at intervals of 1 inch or less. (19) Flux is reapplied to the joint after tacking and the weld is then completed by melting down the flanges and adding a little material from the welding rod where necessary, although as a rule little or no additional metal is needed. This method of welding leaves a good fillet on the lower as well as the upper surface of the joint and is for some purposes, more satisfactory than plain butt welding. Where the bends in flanging run parallel to the grain it is advisable to anneal the sheet before bending by heating to 600 to 750 degrees Fahr., to avoid cracking.

The behavior of the metal in making either butt or flange welds is similar to that of aluminum in that it is necessary to progress continuously at an even speed along the weld. It is difficult to make a new start in a weld which has been allowed to cool or which has burned through. A very small oxyacetylene torch is employed. The same fluxes used in welding aluminum have been found satisfactory for duralumin.

All traces of welding flux must be removed to avoid corrosion. This may be done by completely submerging the part in a 10 per cent solution of sulphuric acid in a non-metallic container, for one hour, followed by through rinsing in running water. Exposure to the air while in the acid will cause local pitting.

Tensile tests on welded joints, heat treated but not dressed, varied from about 50 to 100 per cent of the strength of the sheet, and on dressed joints, heat treated, varied from about 25 to 80 per cent by either method. Heat treatment should follow welding. Without heat treatment there is rapid corrosion along a line parallel to and about an inch away from the welded joint in the presence of moisture, especially salt water spray; see Fig. 8. The weld itself is not attacked. This effect is apparently electrolytic, due to a physical difference between the metal exposed to the heat of welding and the remaining metal. Heat treatment of the whole part after welding eliminates this condition. Heat treatment also greatly increases the strength of welds. Heat treatment may be by either oil or water quenching. Air cooling has been

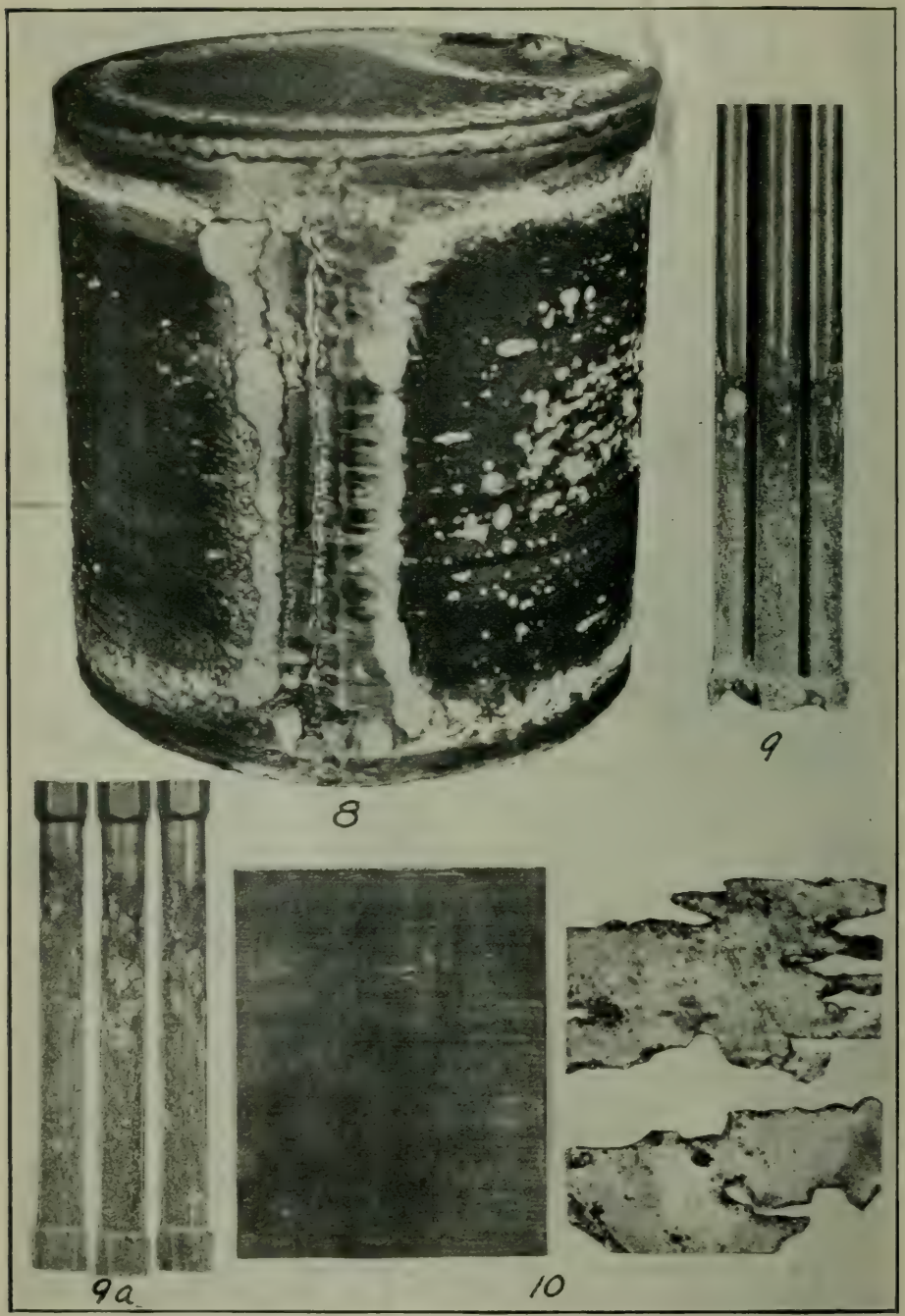


Fig. 8—Corrosion of unheat treated welded duralumin after 5 days in salt water spray test. Figs. 9 and 9a—Heat treated duralumin tubes, perforated after 2 months immersion in tap water. (Dia. ¼ inch, thickness 0.01 inch). Fig. 10—Heat treated duralumin sheet 0.01 inch thick before and after 6 months exposure to salt water spray test.

tried with some success. The greater convenience of air quenching large articles might warrant its use in some cases even at some sacrifice in strength.

Beads, grooves, dished heads, or crowns around welds are often necessary to take care of the high thermal expansion during welding.

Duralumin may be welded to aluminum sheet, and even to copper-aluminum alloy castings, but this tends to induce electrolytic corrosion in the presence of moisture. Plain aluminum welding rod was used with success, but gives a weaker joint, and is subject to corrosion.

Corrosion

The statement that duralumin is not corroded by fresh or salt water should be taken with caution. Heat treated sheet and thin tubes have been perforated after two months immersion in tap water; visible attack setting in within one to two weeks, as shown in Fig. 9. Experiments (20) have shown heat treated duralumin sheet to be rendered entirely worthless after a few months exposure in the salt water spray tests; see Fig. 10. Corrosion in fresh or salt water is manifested by the appearance of a white gelatinous precipitate (aluminum hydroxide?) at localized points on the specimen. This is accompanied by a darkening of the surface. Continued exposure results in blistering, scaling, pitting, perforation and eating away of the sheet, and often by splitting apart at the edges, due to destruction of the interior material. When dried, the precipitate turns to a white powder, apparently aluminum oxide. Immersion in 10 per cent nitric acid removes the products of corrosion without noticeably affecting the metal and facilitates inspection of test specimens. It has been shown (27) that duralumin sheet when exposed to some reagents is subject to a type of corrosion which is truly intercrystalline in character, resulting in brittleness. Comparative tests (20) made on duralumin and commercial aluminum sheet (98 per cent pure) in exposure to salt spray and in immersion in tap water gave distinctly superior results for the aluminum.

Effect of Heat Treatment

Heat treated metal which has been annealed at certain areas, as by welding, is severely attacked at the juncture of the annealed and tempered material, as shown in Fig. 8. Reheat treating the entire part prevents this locallized action. Heat treated duralumin is more resistant to corrosion than the annealed material. The rate of cooling in heat treatment has a strong influence on its resistance to corrosion, as indicated by the salt spray test. This influence is proportionally greater than the influence on the tensile properties. The degree of corrosion, as indicated by the appearance of test specimens taken from the same sheet, heat treated by quenching from 932 degrees Fahr. in various mediums, aged for 10 days, and exposed for 30 days in the salt spray test, may be graded as follows:

	Quenching medium	Degree of corrosion
(a)	Water at 60 degrees Fahr	Very slight
(b)	Water boiling	Slight, but more than (a)
(c)	Quenching oil, at 70 degrees Fahr	Same as (b)
(d)	Air, fan blast 65 degrees Fahr	Severe, scaled
(e)	Still air, 65 degrees Fahr	Very severe. Deeply scaled

Specimens are shown in Fig. 12.

The physical properties of these specimens after heat treatment are discussed under *quenching mediums,* and given in Table I.

Permanence of Polish

Polished duralumin will apparently remain bright indefinitely when not exposed to moisture, and is not stained by handling.

Effect of Gasolene

Neither gasolene nor benzol, although containing considerable quantities of sulphur in solution, have any appreciable corrosive effect on duralumin, heat treated or otherwise.

Salt Spray Test

The salt spray test is a much accelerated test; that is it is much more severe than ordinary atmospheric exposure, even on the sea. In the test, the specimens are suspended in a nonmetallic box with a glass cover, and kept constantly moist with a solution of common salt

Fig. 11—All-Duralumin Seaplane, Dornier, CS-2.

in water, (20 per cent by weight) atomized by means of a compressed air jet. Galvanized steel fittings, intended for use on seaplanes, are required to withstand this test for 100 hours, (4 days), without signs of rust.

Causes of Corrosion

The corrosion of unprotected duralumin in the presence of an electrolyte seems to be a question of time. The action is apparently electrolytic, due to local differences of compositions or of heat treatment in the metal. The segregation of impurities, or of normal constituents of the material is probably responsible for pitting and splitting. The purity and uniformity of the material is no doubt, an important factor. Corrosion doubtless is accelerated by the proximity of metals electronegative to duralumin in the presence of an electrolyte. Corrosion has been ascribed to mechanical strains set up by working aged material. In tests made by the writer, it has never been found that severely bent or cold worked portions of specimens corroded more than unworked

portions. For example, tensile specimens placed in the salt spray test after fracture showed no more severe corrosion at the gaged length than at the butt ends.

Exposure Tests

Some very favorable corrosion tests of duralumin are quoted from foreign sources, as follows:—

U—profiles of duralumin, copper, iron, aluminum alloys, pure aluminum and Electron metal were exposed to the action of sea air on a light ship in the North Sea for three months. These sections were also riveted and screwed together. Duralumin resisted these conditions better than any of the other materials, and showed practically no oxidation. (12).

Tests made at the shipbuilding docks at Vickers, Ltd., in England, by hanging four pieces one foot square so that they were immersed at high tide, but above water at low tide, showed a loss in weight after six months of approximately 0.001 gram per square centimeter. Specimens exposed in the open air alongside a dock for eight years were only slightly discolored and showed the same strength as obtained a week after heat treatment. (6).

Exposure tests made on the roof of a building at the Durener-Metallwerks, Germany, on bars and wires, for a period of 2½ years, showed no evidence of any alteration in hardness or ductility. (13).

Chemical Reagents

The effect of 14 months immersion in hydrochloric, nitric, sulphuric and acetic acids of various concentrations as well as other reagents, has been studied (12). In general, the action of acids is slow.

Like aluminum, duralumin is rapidly attacked by alkalies.

Electrolysis

Metals electrolytically negative to duralumin are copper, brass, bronze, iron, steel, etc. These metals should presumably not be joined to duralumin where subject to moisture. However, the following is quoted from a German source: (13).

"Experiments made on the electrolytic effect from junctions of duralumin with iron or steel show that only insignificant destruction of the iron at such riveted joints takes place in artificial sea water." (13).

Under ordinary atmospheric conditions, when protected from the weather, there would probably be no serious damage resulting from such joints.

Protective Coatings

Spar varnish is a good protective coating for duralumin. The varnish may be tinted by the addition of about 4 per cent of American Blue ground in oil. This makes it easier to see that parts have been properly coated, and is sufficiently transparent to permit inspection for surface defects in the material. Enamel or paint may be applied over the varnish. The direct application of coatings having zinc or lead pigments is not recommended. Powdered aluminum mixed with bronzing liquid, has proved a satisfactory coating on duralumin airplane wings, and certain commercial paints and lacquers have given promising results under test.

Uses

Aircraft

Duralumin is still practically the only suitable material of construction for rigid dirigibles (airships of the Zeppelin type) for which purpose it was originally developed. In these, the frame work is of latticed girder construction consisting of transverse frames spaced by longitudinals. The girders are, as a rule, of triangular section, each corner consisting of a U-shaped channel; these are crossbraced with stamped lattices. The lattices are stamped from strips and are of highly efficient design. Girder joints are made by riveting and are sometimes quite intricate.

After having demonstrated its reliability as a material of constructures for dirigibles; duralumin was employed in Europe in the con-

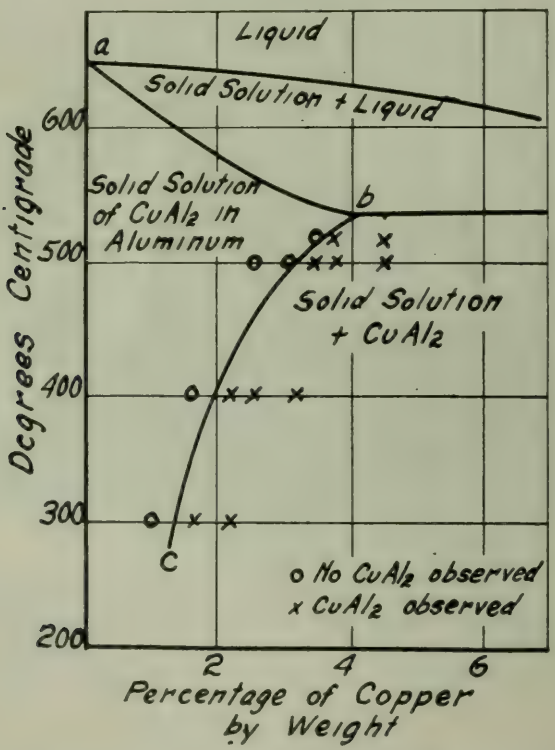


Fig. 12—Partial equilibrium diagram of Copper-Aluminum series showing solubility curve of Cu Al_2 in aluminum. (After Merica.)

struction of airplanes. One of the earliest and most successful of these was the Junker all-metal monoplane. Several successful types of all metal duralumin planes have been developed abroad and new models are being built in this country. In airplane construction, it is necessary that the machine be specially designed to obtain the full structural value of the material. This generally includes using sheet duralumin as a wing covering, where it acts both as a structural mem-

ber and as a wing surface, replacing the usual fabric. Besides lightness and rigidity, it has the advantage over wood and fabric of being non-inflammable. Duralumin is also used in spars, struts, ribs, etc., with a fabric covering. An all duralumin seaplane is shown in Fig. 11.

Automotive

The use of duralumin is rapidly spreading to other industries, where strength and lightness are important, notably the automobile. Worm wheels and gears and helical spur gears of duralumin have given good results when run against hardened steel. Pressures should be well within 30,000 pounds per square inch. Quiet running is claimed. This is probably due to the difference in pitch of the sound vibrations in the two metals.

Duralumin connecting rods running directly on the wrist pins had longer life at this point than with the conventional bronze bushed rod of equal bearing area. Tests of duralumin used as a bearing metal against babbitt, show that for shaft speeds over 700 revolutions per minute and loads over 200 pounds per square inch, duralumin bearings develop less friction, remain cooler and show practically no loss in weight under most severe conditions. (15)

General

The many valuable properties of duralumin open an almost unlimited field of usefulness, for example: Reciprocating parts for engines and machinery, gears, automobile parts, wheels, and bodies, handles, miscellaneous hardware, lawn mowers, surgical and dental accessories, scientific, electrical and musical instruments, telephone and radio apparatus, office equipment, metal patterns, forged, pressed and stamped shapes of great variety. Its bell-like tone suggests a possible use for chimes and gongs. The duralumin alloys in various forms are now obtainable from at least three competent manufacturers in this country, and from foreign sources.

Constitution
Metallography and Theory of Heat Treatment

Hardening and Ageing

The writer will endeavor to briefly recapitulate the theory of heat treatment of duralumin as presented in articles by Merica (1) (8) Jeffries (7) (28) and their associates.

In spite of an apparent difference in behavior, there is a marked analogy between the heat treatment phenomena of duralumin and steel. The hardening of duralumin in heat treatment depends primarily on the presence of small amounts of copper. Copper forms a compound, $CuAl_2$, with aluminum. (Compare the compound Fe_3C, between carbon and iron, in steel). This $CuAl_2$ forms an eutectic with aluminum which is relatively hard and brittle. (Compare pearlite in steel). This eutectic contains about 32 per cent copper by weight and melts at 1005 degrees Fahr. It is found in the various casting alloys of copper and aluminum. (Notably "No. 12", Cu. 8 per cent Al 92 per cent. These become harder and more brittle as the copper content ($CuAl_2$) increases.) (Compare hard and brittle high carbon steel).

$CuAl_2$ is soluble in solid aluminum in small amounts increasing from

about 1 per cent copper by weight at room temperature up to a maximum corresponding to about 4 per cent of copper by weight, at 1005 degrees Fahr. (above which the $CuAl_2$ melts). This is clearly shown in the partial equilibrium diagram, Fig. 12, by Merica (1).

Therefore, if a copper-aluminum alloy containing about 4 per cent Cu by weight be heated to nearly 1005 degrees Fahr. the $CuAl_2$ will go into solid solution (possibly as Cu in aluminum) (Compare solid solution of carbon or carbide in steel). The amount of $CuAl_2$ in solution will depend upon the temperature. The hardness and tensile strength of duralumin increase with the temperature to which it is heated before quenching up to 1005 degrees Fahr. and then decrease rapidly, see Fig. 1. That is, these properties depend upon the amount of $CuAl_2$ which is in solution at the moment of quenching. Heating above 1005 degrees Fahr. melts the $CuAl_2$ and damages the material. When the saturated solution of $CuAl_2$ in aluminum is quickly cooled, as by quenching, the

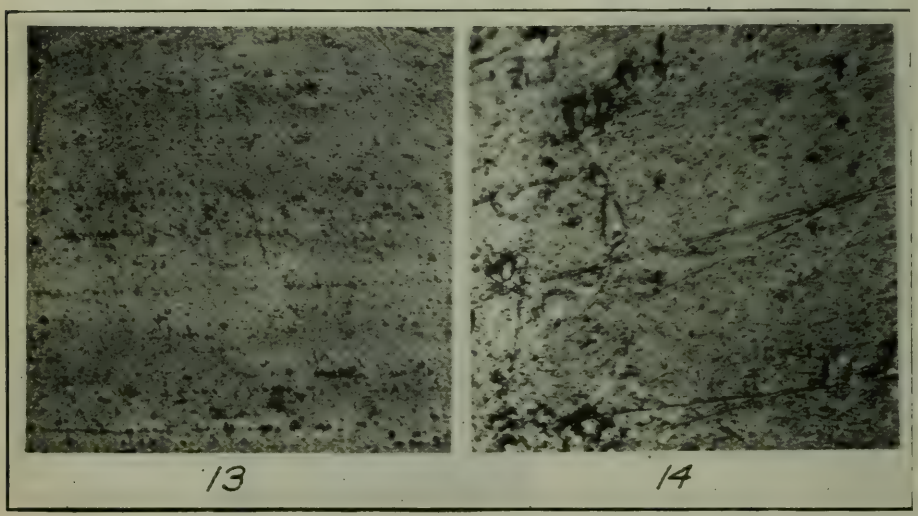


Fig. 13—Heat treated Duralumin sheet. X 100. Longitudinal section polished, not etched. Dark particles probably undissolved or excess Cu Al_2 and impurities. Fig. 14—Same as Fig. 13 magnified 500 times.

$CuAl_2$ is held in solid solution in a state of unstable equilibrium, (or is precipitated in extremely small, perhaps molecular, particles, not visible under the microscope).

(Jeffries (7) points out that the smallest globule of $CuAl_2$ resolvable under the microscope contains about two billion (2,000,000) molecules). If the cooling is slow, as in the furnace, the $CuAl_2$ will be precipitated in relatively large particles, perhaps large enough to be seen under the microscope. When the rate of cooling has been very slow, no change in physical properties takes place on ageing. After rapid cooling, (quenching,) the hardness and strength of the metal increases at ordinary temperatures, reaching a maximum in about 10 days, after which they remain permanent. This is called "ageing." See Fig. 4.

If this alloy is quickly cooled and then kept at the temperature of liquid air, no ageing takes place. If it is then raised to ordinary room temperature, ageing proceeds. In a climate as cold as liquid air we

would have to heat duralumin after quenching to produce any change in properties. Ageing, even at normal room temperature must, therefore, be considered a form of *heat* treatment.

Hardening Due to Precipitation of $CuAl_2$

Pure aluminum unlike ferrite, undergoes no known allotropic changes between room temperature and its melting point. But if duralumin is reheated immediately after quenching, an evolution of heat occurs at about 480-530° F. (250-275° C.) (1) This is not an allotropic change, and is not reversible on cooling. Merica (8) has shown that this heat effect is due to the precipitation of $CuAl_2$, which was held in solid solution by quenching. When duralumin is kept at a very low

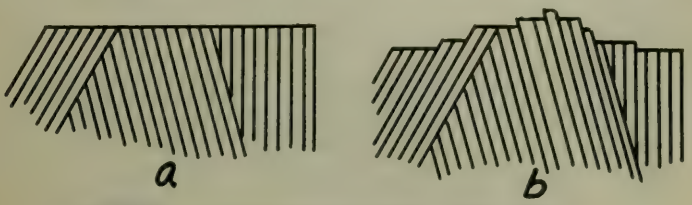


Fig 15—Slip planes in crystals. (After Desch.)

temperature (as in liquid air) after quenching, the $CuAl_2$ is held in unstable equilibrium. If allowed to remain at room temperature, or if heated to 212 to 305 degrees Fahr. the precipitation takes place slowly and gradually and we have the phenomenon of ageing. The same evolution of heat doubtless takes place during such ageing but is too slow to be noticeable. (If the quenched duralumin has aged to maximum hardness, or if it has been annealed, no evolution takes place on heating to 480 to 530 degrees Fahr.)

When aged at ordinary temperature, or even at 212 or 305 degrees Fahr. the precipitated particles are too small to be seen under the microscope. No difference can therefore be detected optically between the microstructure of aged and freshly quenched specimens. (8) Some particles of $CuAl_2$ are generally visible after heat treatment, under ordinary magnifications, perhaps due to imperfect solution or excess copper; see Figs. 13 and 14.

The hardening of duralumin is therefore due to the precipitation of minute particles of $CuAl_2$ from solid solution, temporarily held in unstable equilibrium by sudden cooling. (8) However, if duralumin is quenched and then aged at a temperature of about 395 degrees Fahr. the hardness increases rapidly to a maximum and then *decreases* (1). If the ageing temperature is still further raised, softer material results. Upon heating to the *quenching* temperature and cooling very slowly, particles large enough to be visible under the microscope are formed, and the material is very soft, much softer than even freshly quenched material, having a scleroscope hardness of 7 to 10 as compared to 16 for the latter. Duralumin so annealed hardens little or none upon ageing. Ageing therefore consists in the formation of fine nuclei of $CuAl_2$ which coalesce into larger particles at ordinary temperature and into still larger particles at higher temperatures (above 395 degrees Fahr.)

Critical Dispersion

Immediately after quenching the precipitated particles of $CuAl_2$ are

very fine and the material is soft. Upon normal ageing the particles become larger and the material reaches maximum hardness. At higher temperatures the particles increase further in size, but the hardness decreases. In general, the tensile strength follows the hardness. It is therefore, evident that the maximum hardness and strength of duralumin depends upon the formation of particles of $CuAl_2$ of a particular average size, intermediate between the extremely fine ones produced after quenching and the coarser ones produced by heating above 395 degrees Fahr. The size of particles for maximum hardness may be called the "critical" size, or according to Jeffries (7), the condition of "critical dispersion." The growth of these particles depends upon molecular migration, which depends upon both time and temperature, but primarily upon temperature. At ordinary temperatures hardness attains a maximum in about 10 days and then remains permanent. At 212 to 305 degrees Fahr. the maximum is reached more quickly and is somewhat higher, but is also permanent. At 395 degrees Fahr. the critical size and maximum hardness are reached quickly, but growth continues with consequent softening. Therefore, temperature, not time, is the determining factor.

Ship Interference Theory

Jeffries and Archer (28) have offered a very reasonable and interesting explanation for the hardening effect of these particles of "critical size." They first define hardness as "resistance to permanent deformation" and state that metals owe their hardness and strength primarily to the attracting forces between their atoms. The full effect of this atomic cohesion is never realized, for "rupture always takes place by degrees and the breaking of atomic bonds is not simultaneous." The regular arrangement of the atoms in the crystals of metals gives rise to planes having a low resistance to shearing stress, called "slip" planes. (It is easier to slide the atoms past each other than to pull them apart.) The deformation or failure of metals usually occurs along "slip" planes in the crystals, as illustrated diagrammatically in Fig. 15, after Desch, and their appearance in ferrous and other metals after straining is well known. Anything which will interfere with this slip tends to increase the hardness and strength of the metal.

Quoting Jeffries and Archer further:—"The hardening and strengthening of metals by any of the known methods may be considered as due principally to interference with slip.... In duralumin we are dealing with an aggregate composed of a relatively weak matrix—aluminum,—greatly strengthened by the presence of small, hard, *diconnected* particles of $CuAl_2$." In explaining the manner in which this strengthening is accomplished, the authors compare a crystal of metal, with its parallel planes of easy slip, to a stack of iron plates placed in a strong magnetic field which acts at right angles to their surfaces, as illustrated in Fig. 16. ("This stack of plates presents a rather close analogy to the conditions obtaining in a ductile crystal, especially in that the forces which hold the atoms of a crystal together are probably electromagnetic in character.") The plates would slide over each other much more easily than they would pull apart. The force required to overcome such sliding or slip is analogous to that required to produce deformation (or rupture) in a ductile metal. Fig. 17 shows how these plates

might be "keyed" together, by the presence of many small hard spherical particles, so that slip would be greatly resisted. A similar condition exists in duralumin when the particles of $CuAl_2$ have coalesced to the critical size. If a number of the key particles were united into a single large particle, as shown in Fig. 18, there would be many planes of slip left unkeyed, and resistance to deformation would be decreased. This explains the softening of duralumin produced by ageing at higher temperatures (395 degrees Fahr. and up) or by annealing. The key particles have massed into larger particles which are relatively far apart, leaving the intervening spaces free to slip.

The strengthening effect of the hard particles evidently increases with their number, and not with their size. However, when the particles are very small, as just after quenching and therefore most numerous, the material is soft. The rule that hardness increases with the *number*

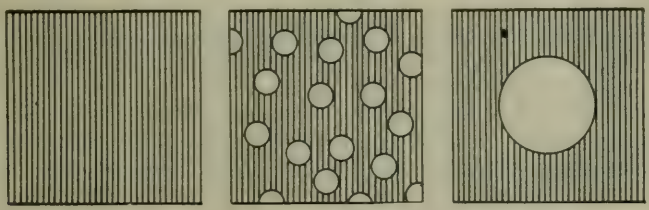


Fig. 16 Fig. 17 Fig. 18

Fig. 16—Set of planes of easy slip in a crystal having no internal slip interference. Fig. 17—Slip planes "keyed" by hard particles. Fig. 18—Reduced slip interference. Hard constituent gathered into a single large particle, leaving many planes without reinforcement. (After Jefferies and Archer.)

of particles therefore "must reach a limit as the particles approach atomic dimensions..... The key formed by the little group of aluminum atoms surrounding the copper atoms in the solid solution is more easily sheared through than is a particle of crystalline $CuAl_2$. The critical dispersion for maximum hardness should therefore consist of the smallest possible particles having the characteristic crystallinity of the compound." (28). In other words the atoms in solid solution exert a hardening effect (freshly quenched duralumin is harder than pure aluminum) but they are not as good keys as are small bodies of $CuAl_2$. There is probably a limiting size below which $CuAl_2$ particles do not have the characteristic hardness and strength of the material. When the particles are too small they are not strong keys; when they are too large, they are stronger but too far apart, leaving unkeyed areas. The intermediate or critical size therefore gives the most effectual resistance to slip and consequently the greatest hardness and strength.

The writer has endeavored, above, to outline the "critical size" theory, as presented in papers by Merica, (1) (8), Jeffries (7) (28) and their associates. It seems that the explanation of hardening might be simplified by considering that the $CuAl_2$ is held in solid solution in quenching, remains so at very low temperatures, as in liquid air, and is precipitated slowly at ordinary temperatures, and more rapidly up to 395 degrees Fahr. while at 480 to 530 degrees Fahr. all is suddenly precipitated with evolution of heat, as shown by Merica. If $CuAl_2$ goes into solid solution as atoms of Cu in Al on heating, and is so held upon quenching, the hardening effect upon ageing may be simply due to the *precipitation* of the most minute possible particles of $CuAl_2$, hardness increasing as more of the $CuAl_2$ is precipitated

until all is precipitated except that normally soluble at room temperature. Higher temperature, by causing coalescence of the precipitated $CuAl_2$ into larger particles, would cause softening by reducing the *number* of "keys," as explained by Jeffries. The maximum quantity of precipitated $CuAl_2$ dispersed in the smallest possible particles (molecules?) would have the maximum hardening effect. On this basis it would apparently not be necessary to explain the "critical size" phenomenon as done by Jeffries and Merica.

Continuing with the effect of slip interference on tensile properties: Ductility depends upon the amount of deformation (slip) which can be produced in a material before rupture. If the resistance to slip becomes as great as the direct rupturing strength (pulling apart) of the atomic bonds, brittleness, with relative hardness, results. Aged duralumin is therefore less *plastic* than when either freshly quenched or annealed.

Tensile specimens tested at intervals from 5 minutes to 6 days after quenching (20) show an increase of hardness and tensile strength, but an almost uniform elongation; see Figs. 4 and 5. The elongation of test specimens is evidently not an index of the plasticity (workableness) of the material. It is interesting to note that annealed material has a lower elongation (10 to 14 per cent) than that of the stronger and harder tempered material (18 to 25 per cent) see Table III.

Jeffries and Archer (28) point out that cementite Fe_3C, in steel may have a keying effect in the matrix of ferrite, similar to that of $CuAl_2$ in duralumin. The hardening of duralumin at atmospheric temperatures also has a parallel in the hardening of some of the high carbon manganese and tungsten steels by precipitation of finely divided cementite from austenite when heated to moderate temperatures. (8) (28).

Other Constituents

In the foregoing discussion of hardening only the elements copper and aluminum have been considered. Referring again to Merica (1) (8):— The characteristics of duralumin depend fundamentally upon the constituent $CuAl_2$, but the hardening effect is greatly increased by the presence of the usual small amounts (up to 1 per cent) of magnesium in its composition. Magnesium forms a eutectic with aluminum Mg_4Al_3 whose melting point is about 860 degrees Fahr. and which contains about 36 per cent of Mg. Magnesium enters into solid solution in aluminum, in increasing amounts with temperature up to about 12 per cent at 860 degrees Fahr.

Alloys of aluminum with magnesium alone, in amounts up to 3 per cent Mg do not harden upon ageing. The action of the magnesium in duralumin is to *intensify* the hardening effect of the $CuAl_2$. Here again is an analogy with steel, in the action of small amounts of nickel in increasing the hardening effect of carbon in steel. The exact reason for this intensifying action of magnesium is not clear, but it may be due to its effect upon the silicon or iron which are present as impurities. Magnesium combines with silicon to form Mg_2Si, visible as a blue constituent under the microscope. The removal of the silicon in this manner may increase the hardness of the metal. (1).

Iron forms a eutectic, $FeAl_3$, with aluminum, which is often found to surround particles of $CuAl_2$. Magnesium may lower the melting

temperature of this envelope, thereby allowing the $CuAl_2$ to diffuse more readily in the aluminum.

The eutectic Mg_2Si melts at about 840 degrees Fahr. This, and the melting of the Mg_4Al_3 eutectic, at 860 degrees Fahr. accounts for the hot shortness of duralumin above that temperature. Forging and rolling should therefore be done below 840 degrees Fahr. although the material might be preheated to about 930 degrees Fahr. to dissolve the $CuAl_2$.

The writer has found no explanation of the function of manganese in duralumin. It has been stated that it gives an increase in tensile strength of about 5000 pounds per square inch, and also increases the hardness and decreases the ductility slightly.

Etching

The microscope is much less useful in the study of duralumin than in steel because the changes produced by heat treatment are not visible, even under high magnification. The microscope may be used in the examination of the grain size, microflaws, the effects of working, and the presence of various constituents and impurities, etc. Duralumin is subject to many of the internal structural defects common to steel, such as inclusions, segregations, laminations, blowholes, fissures, pipes, etc.

Many features of the microstructure are visible in the polished section without etching.

Metal polish on broadcloth has been found satisfactory for final polish, and better than rouge or aluminum oxide. The latter are apt to leave a stain. For grain structure etching with 10 per cent sodium hydroxide or 5 per cent hydrofluoric acid is reccommended, while for microconstituents 0.1 per cent sodium hydroxide plus 10 per cent alcohol in water is superior. A 10 per cent solution of nitric acid is useful for some purposes. Sodium carbonate has also been used.

The microconstituents of duralumin are described, with photographs, in references (1) and (8).

Bibliography and References

(1) **"Heat Treatment of Duralumin"** by P. D. Merica, Waltenburg and Scott, Bureau of Standards, Scientific Paper No. 347.

(2) **"Heat Treatment of Aluminum Alloy Castings,"** by Jefferies and Gibson. A paper presented at the Sept. 1919 meeting of the Am. Inst. of Mining and Metallurgical Engineers, at Philadelphia, Pa.

(3) **"Metal Construction of Aircraft, Advantages of Steel and Duralumin; Their Preparation and Possibilities,"** by Thurston in Aeronautics, May 22, 1919.

(4) **"Preliminary Data, Alloy 17S,"** Aluminum Company of America.

(5) **"Aluminum and its Light Alloys"** (V) by P. D. Merica, in Chemical and Metallurgical Engineering, Oct. 15, 1918.

The writer wishes to express his grateful acknowledgment to Commander G. C. Westervelt, Manager, and Commander H. C. Richardson, Chief Engineer, of the Naval Aircraft Factory, for permission to publish this paper, and to Mr. T. W. Downes for assistance in gathering and preparing data, to Mr. N. S. Otey for physical tests, and to Mr. S. Philips for notes on British practice, as well as to others who made valuable contributions.

(6) **"The Properties and Use of Duralumin,"** Data by Vickers, Ltd. England.
(7) **"The Micro-Mechanism of the Ageing of Duralumin"** Note by Zay Jefferies to British Institute of Metals, Sept. 24-25, 1919. Engineering (London), October 10, 1919.
(8) **"Constitution and Metallography of Aluminum and its Light Alloys with Copper and Magnesium"** by P. D. Merica, Waltenburg and Freeman, (Bureau of Standards Scientific Paper No. 337), also, Chemical and Metallurgical Engineering, Vol. 21, No. 11, Oct. 29—Nov. 5, 1919.
(9) **"Light Aluminum Alloy Castings, Effect of Heat Treament,"** by P. D. Merica & C. P. Karr, Bur. Stds. Tech. Paper No. 139.
(10) **"Aluminum and Its Alloys,"** by C. Grard (D. Van Nostrand Co.)
(11) **"Solders for Aluminum,"** Bureau of Standards. Circular No. 78.
(12) **"Aluminum and Its Light Alloys,"** Bureau of Standards. Circular No 76 (With Bibliography on Duralumin).
(13) **"Duralumin"** by Unger and Schmidt. Translated from Technische Berichte Vol. III, Section 6, by Starr Truscott, USN.
(14) Booklet on **"Duralumin"** published by Baush Machine Tool Co.
(15) Paper entitled **"Duralumin as a Material for Worm and Other Gearing,"** presented before American Gear Manufacturers Association, at Rochester, N. Y., Oct. 13 to 15, 1921, by Robert W. Daniels, of the Baush Machine Tool Co.
(16) Data Sheets of Baush Machine Tool Co.
(17) **N. A. F. Specifications A-11, Duralumin Sheets, Rods and Wires.**
(18) Bureau of Aeronautics' Specif. 53-B, **Aluminum Alloy Sheet.**
(19) **"Welding Duralumin"**—H. C. Knerr, Automotive Industries, May 4, 1922.
(20) Experiments at the Naval Aircraft Factory, U. S. Navy Yard, Philadelphia, Pa.
(21) **"Manufacturing Possibilities Offered by Duralumin,"** by W. B. Stout in Automotive Industries, Oct. 6, 1921.
(22) **Duralumin—Its Properties and Commercial Possibilities."** by Wm. B. Stout, Presented before Indianapolis Convention American Society for Steel Treating, Sept. 1921.
(23) **"Alloyed Aluminum as an Engineering Material,"** by G. M. Rollason. An abstract of a paper presented at a meeting of the Metropolitan Section of the American Society of Mechanical Engineers, Feb. 10, 1920.
(24) **"Castings of Light Aluminum Alloys"** by R. J. Anderson in the Iron Age, Feb. 17, 1921.
(25) A thesis on tests of Special Duralumin Shapes as columns to determine their adaptability for use in rigid airship construction—by Ervin Harsch and E. P. Whitehead, Mass. Institute of Technology.
(26) **"Development of Metal Construction in Aircraft,"** by J. S. Nicholson, Engineering, March 1920.
(27) **"Brittleness Developed in Aluminum and Duralumin by Stress and Corrosion,"** by Rawdon, Krynitsky & Berliner, Chemical & Metallurgical Engr., Jan. 25, 1922., p. 154.
(28) **"The Slip Interference Theory of the Hardening of Metals,"** Zay Jefferies & R. S. Archer, Chem. & Met., June 15, 1921, p. 1057.

SOME NOTES ON THE INSPECTION OF STEEL FOR AUTOMOBILE USE

By R. J. Allen

IN THE production of any highly developed machine such as the automobile, considerable attention is paid to the dimensional inspection of all parts while but comparatively little attention is paid to the inspection of the quality of material used other than to see that its surface is of the desired hardness and free from seams or cracks. The reason for this is probably twofold; first, inaccurately machined parts, aside from being non-interchangeable, cause trouble in assembly and also prevent the smooth operation demanded by sales, while unsound or improperly heat treated parts do not, in most cases, cause trouble until after they have been in service for some time; second, instruments for checking the dimensions of any machined surface have been developed to a much greater extent than have instruments for peering into the interior of metals so that the inspection of the latter is necessarily more troublesome and uncertain.

Tests of Inspecting Not Extensive Enough

The magnetic analysis and the X-ray offer possibilities for the future, but at the present, aside from surface hardness, all forms of physical tests are more or less destructive in nature and hence cannot readily be applied to the part intended for service. The usual practice, therefore, is to select representative samples from the lot of material as received from the mill, make tests on these, and assume the remainder of the stock to be of the same nature; material accepted by these tests is then passed for use to be worked into forgings or machined parts. If the tests are numerous enough and the results uniformly good it is perhaps logical to assume that the material is satisfactory but subsequent to these tests carelessness on the part of the forgeman through improper hammering or excessive overheating, or carelessness on the part of the heat-treater may leave some of the pieces in such a state, not revealed by the surface condition, that ultimate failure in service must result; the representative tests on the original stock therefore cannot be regarded as a true criterion of the finished part.

To the manufacturer whose reputation is built on the continuity of service of each individual car over long periods of time without replacement or adjustment because of breakage or excessive wear, it is essential that the soundness of each important or highly stressed part be assured before it is passed for service. In vital parts such as steering members where failure may result in serious accident this is doubly important. With present facilities the only reliable, and at the same time practical way, of obtaining this assurance is by means of the individual fracture test; this, while not made on the material actually used in the part, can with the aid of a properly attached prolongation, be carried so close to it that the possibility of variation is indeed slight.

Fracture Tests

The accompanying illustration, Fig. 1, shows a few of the parts of the Rolls-Royce chassis provided with test prolongations. These extensions are left undisturbed until after the pieces have passed all stages of heat treatment and final hardness inspection when they are nicked, fractured off, and ex-

A resume of a talk given before the Providence Chapter. The author, R. J. Allen, is metallurgist, Rolls-Royce Co., Springfield, Mass.

amined. It will be noted that the prolongations are placed so that when fractured they expose a transverse section of the material. Attention is called to the ball-end for steering piece, a part machined from bar stock, with its double prolongation, the upper one when fractured to reveal the depth and refinement of case, the lower one, bent through an angle of 90 degrees, to reveal the ductility of the core.

The fractures illustrated in Fig. 2 were made on two similar forgings forged from the same lot of uniformly good steel. Both pieces had the same

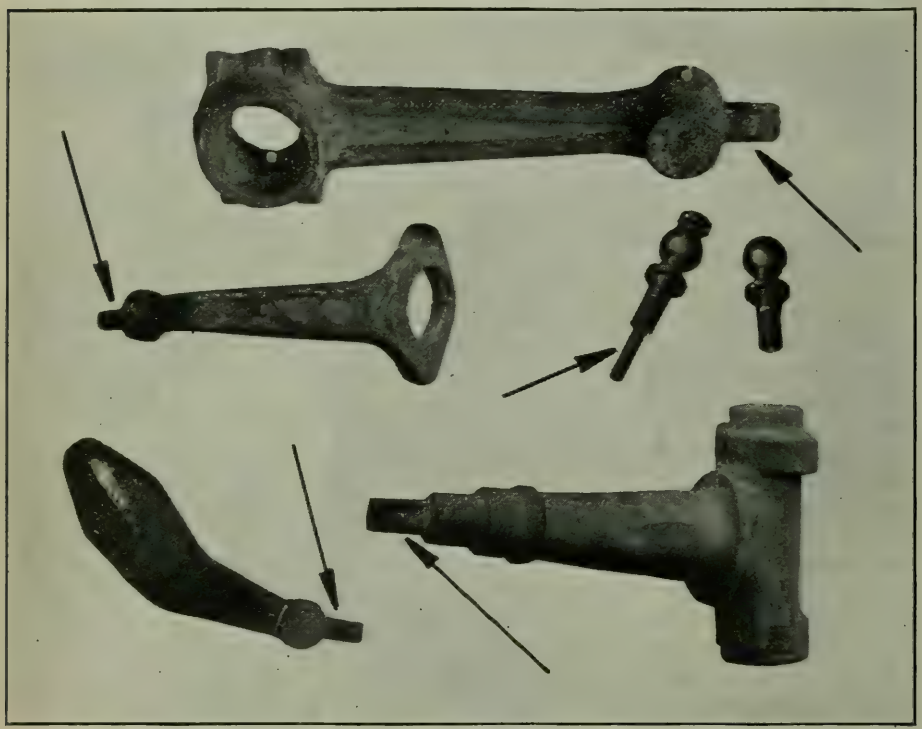


Fig. 1—Method of attaching test prolongations to forgings. The arrows indicate the location of the prolongation.

Brinell hardness following the standard heat treatment and outwardly were in appearance the same. "A" exhibits a good tough condition in the metal while "B" exhibits a decidedly brittle condition due to excessive heating during forging. The fractures on the small test prolongations clearly indicate the condition that existed in the forging proper. A section of the forging in question shows the proximity of the forging fracture to that of the test prolongation. Fracture "B" is representative of the condition of three out of a lot of 200 forgings; the remainder were all acceptable pieces. Without the test prolongations the three, although decidedly inferior to the others, would undoubtedly have been passed for use.

From the appearance of the fracture one can tell whether the material is sound and in the structural condition desired and also one can predict with considerable accuracy the results that would be obtained on a physical test. The prediction as to physical results, however, like the file test for hardness or the color observation for temperature, is not absolute and recourse must

frequently be had to some standard form of physical test just as the feel of the file must be checked against the scleroscope and the color against the pyrometer.

Physical Tests

The forms of physical test, excluding hardness which is nondestructive, against which the fracture may be checked, vary. The value of the tests

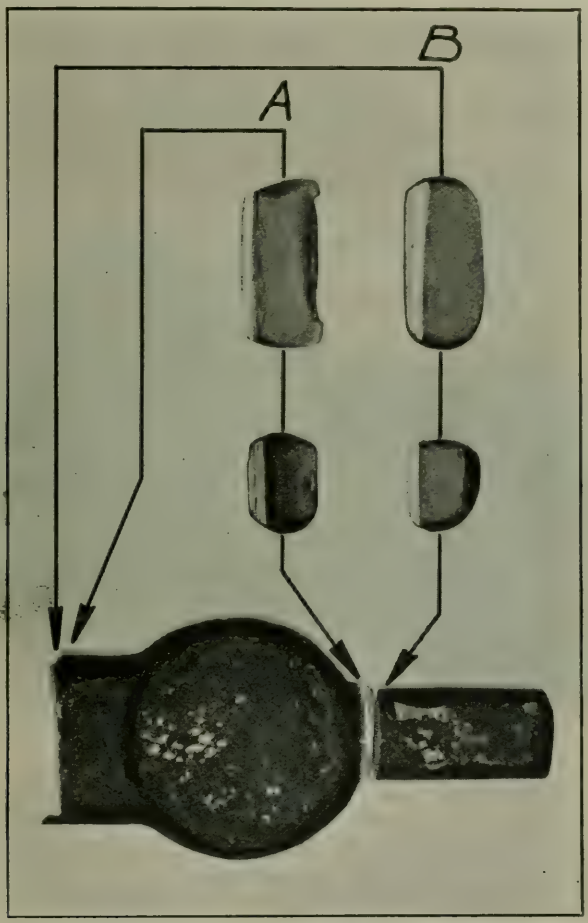


Fig. 2—Shows the manner of using test prolongations. The fracture reveals the structural condition in the forging.

selected, however, depends upon the closeness with which they duplicate actual service conditions. The tensile test is undoubtedly fundamental but its static form of loading does not approximate very closely the condition under which most parts are stressed. Assuming that the design is reasonably correct, it is seldom that a piece snaps off short in service under impact conditions and hence the Izod test, although commonly used, is not representative. Pieces will fail occasionally, however, through fatigue as the result of small blows repeated many times and alternately stressing the fibres in tension and compression; the Stanton test, with its fracture showing all the

characteristics of a fatigue failure, duplicates these conditions closer than any other form of test tried up to the present time.

Repeated Impact Tests

The Stanton machine, of English origin, has been used in conjunction with the tensile with very satisfactory results on individual crankshafts, front axles, and on representative pieces selected from small batches of other parts which in service are subjected to impact and reverse stresses. Its ability to discriminate between suitable and unsuitable material has been demonstrated by

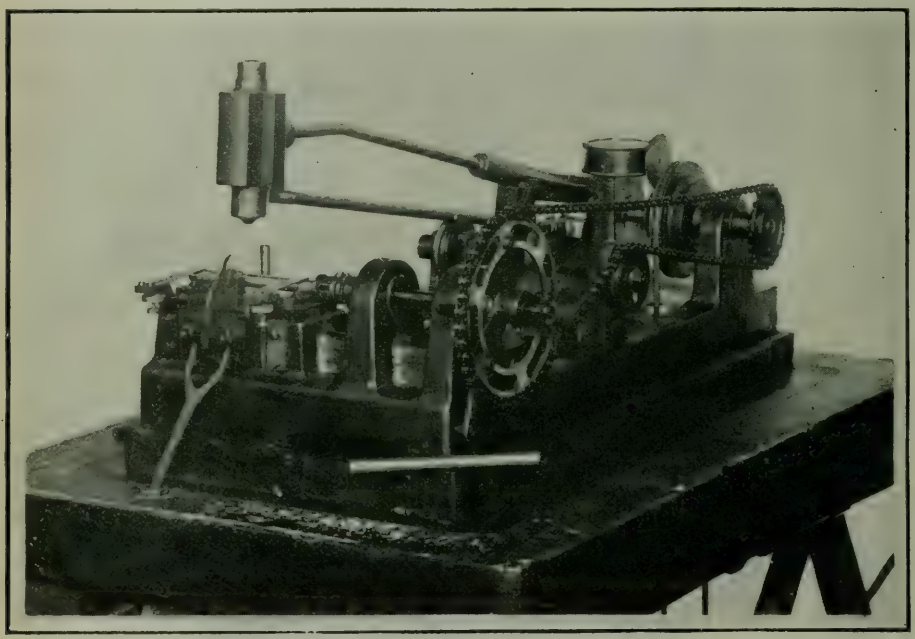


Fig. 3—The Stanton repeated impact testing machine.

the closeness with which its results check life tests made on finished units such as road springs. The test is rather unique in that, aside from duplicating service conditions, reliable results may be obtained in a comparatively short time, about one hour, and also results may be duplicated with considerable accuracy, which is not the case with most impact forms of test. The principle of the test is being made use of by some American instrument manufacturers, and machines, slightly modified in form, are being offered for use.

The Stanton machine is illustrated in the accompanying photograph, Fig. 3. The test piece, which is one-half inch in diameter and six inches long, has a fifty-thousandths square groove cut around its periphery near the center in order to localize the stresses. The piece, placed on two anvil supports some four and one-half inches apart, is set with the groove midway between the supports and directly under the hammer. The hammer is raised by means of a cam to the desired height, usually two inches, from which it falls by gravitation onto the test piece at the rate of one hundred blows per minute. Each

(*Continued on Page* 97)

BIBLIOGRAPHY OF HIGH SPEED TOOL STEELS

The following bibliography covers the literature available on High Speed Tool Steels. This bibliography was prepared by the Engineering Societies Library, New York City, for the use of the Committee on High Speed Tool Steels of the Division of Engineering, National Research Council. The bibliography is complete up to May 20, 1922, and covers the search of the literature as shown at the conclusion of this work.

MANUFACTURE OF HIGH SPEED STEEL

1900

Steel for High-Speed Cutting Tools. (In Mechanical Engineering, Vol. 6, p. 685-6.) Editorial concerning the patent, specification of the Taylor-White process.

The Taylor-White Process of Treating Tool Steel. (In Mechanical Engineering, Vol. 6, p. 699-702, No. 17; American Machinist, Vol. 23, p. 1169-70.) Reprint of the British patent 10738 of 1900.

1901

The Taylor-White Process of Treating Tool Steel, and its Influence on the Mechanic Arts. By C. Day. (In Journal of Franklin Institute, Vol. 152, p. 161-78; abstracted in Engineering, Vol. 72, p. 416; Mechanical Engineering, Vol. 8, p. 574-5, 584-5; Iron Age, Vol. 68, Sept. 19, p. 10-13.) Outline of the Taylor-White process, application of the Link-Belt Engineering Co.'s Works.

Ferneres uber den Taylor-Whitessachen Werkzeugstahl. By G. Reuleaux. (In Vehr. des Vereins zur Beförderung des Gewerbfleisses. p. 128, Stahl und Eisen. Vol. 21, p. 37-40.) More information on the Taylor-White tool steel. Description of process of manufacture, application, cutting speeds; discussion.

Rundschau. (In Zeit. des Verein deut. Ing., Vol. 45, p. 462-5.) Round-table on high speed steel, discussing introduction of new steel by the Bethlehem Steel Co., knowledge obtained by the Bohler Co., process of manufacture of their Rapid steel, tests published in American Machinist, Aug. 16, 1900; Stahl und Eisen, Feb. 15, 1901, Jan. 1, 1901.

Das Wesen des amerikanischen Schnelldrehstahles und des Taylor-White-Verfahrens und Uber die Ergebnisse mit Deutchen Schnelldrehstahlen. By O. Thallner (In Zeit. des Ver. deut. Ing., Vol. 45, p. 1609-10.) The American high-speed steels, the Taylor-White process and the results with German high-speed steel.

1902

High-Speed Tool Steels. (In Engineering, Vol. 73, p. 689.) Note referring to Taylor-White process steel at Paris Exhibition of 1900. Investigation of the "Berliner Bezirksverein Deutscher Ingenieure," paper of O. Mulacek in Stahl und Eisen concerning Extra. Diamant 000 steel produced by the Poldihitte

Kladno, and his theory of the hardening being caused by the presence of carbides.

An Improved High-Speed Tool Steel. (In Mechanical Engineering, Vol. 10, p. 773.) Paragraph concerning steel produced by a new process at the Bismark Furnace in Silesia, Germany. Comparative figures of Taylor-White steel and carbon tool steel.

Schnelldrehstahle und deren Anwendung. By O. Mulacek. (In Stahl und Eisen., Vol. 22, p. 454, p. 454-6, 528-30.) High speed steel and its use, composition, theory of the hardening of the steel, use in cutting, machines, speeds and tests. Paper read before the Mittelthuringer Bezirkvrein deutscher Inzenieure.

A New High-Speed Steel. (In American Machinist, Vol. 25, p. 666-7.) Editorial concerning Novo steel of Jonas & Culver, Sheffield, England.

New Tool Steels and Their Advantages. (In Iron and Coal Trades Review, Vol. 64, p. 1516-8.) Results of tests of new high speed steels made by Jessop & Sons, Jonas & Culver, the Berling Section of the Society of German Engineers Schoeller & Co., followed by outline of Taylor-White process, that data on saving by use of high speed tools, and data on pressure and feeds to be used.

Schnell-Drehstahlfabrication.. By Sievers. (In Stahl und Eisen, Vol. 22, p. 579-80.) High-speed steel manufacture. Uses of steels made by Seehohm and Dieckstahl, influence of manganese, molybdenum, tungsten and chromium in the special steels. Paper read before the Verein zur Beförderung des Gewerbfleisses.

1903

The Analysis of High-Speed Steel. (In Engineering, Vol. 96,. p. 566.) Resume of the methods of analyzing high-speed steel for carbon, silicon, manganese, phosphorus, sulphur, tungsten, chromium, molybdenum, vanadium and titanium.

The New Tool Steel and Its Effect on Machine Shop Methods.. By C. T. King (In Wisconsin Engineer, Vol. 7, p. 255-61.) Development of tool steel, discovery of high-speed steel, cause of change in steel structure by heat-treatment

High-Speed Cutting Steel. By J. Meley. (In Iron and Coal Trade Review, Vol. 66, p. 299-300; abstract in Mechancial Engineering, Vol. 11, p. 197-8.) Progress made in the manufacture of high-speed tool steel in the Sheffield District, and the results of its use in English workshops.

Rapid Tool Steels. (In Engineering, Vol. 76, p. 255-6; Iron Age, Vol. 72, Sept. 17, p. 42-3.) Discussion of various tests resulting from the exhibition by the Bethlehem Steel Co. of the working capacity of the Taylor-White tools at the Paris Exhibition of 1900; the Berlin trials, and the theories of Reiser and Spuller.

Uber das Wesen der Schnelldrehstahle. By F. Reiser. (In Stahl und Eisen, Vol. 23, p. 131-2.) On the properties of high speed steel, history, self-hardening properties of Mushet Steel, Analyses of Bohler rapid self-hardening steels.

The Structure of High-Speed Steels. By E. L. Rhead. (In Engineering, Vol. 95, p. 331, 333, 399, 423.) Present theory that the granular structure of tungsten chromium, nickel, molybdenum or vanadium may account for high cutting speed. Letters calling author's attention to Spuller's carbide theory.

High-Speed Steel. By H. W. Rushmer. (In Iron Trade Review, Vol. 36, p. 50-1,

Sept. 24; American Machinist, Vol. 26, p. 1270-81.) Discovery of Taylor-White process, superiority of new steels, annealing, forging and tempering high-speed steels.

Zur Kenntnis der Theorie der sogenannten Rapid und Naturharten Stahle. By J. Spuller. (In Chem. Zeitung, Vol., 27, p. 165-6.) On the knowledge of the theory of the rapid and self-hardening steels, considers that as the carbon of the iron carbide becomes mobile at about 1000 degrees Cent., it passes out of the iron carbide and forms chrome carbide, tungsten carbide, etc., playing a most important part in imparting hardness to the steel.

1904

Beitrang zur Kenntnis and Theories des Schnelldrehstahls. By H. Eckardt. (In Stahl und Eisen, Vol. 24, p. 611-3, extract in American Machinist, Vol. 27, p. 1080-1.) Contribution to the knowledge and theory of high speed steels. Discussion of the properties of the Taylor-White and European steels made after the Taylor-White process. Deals especially with the cutting and high-speed qualities.

The Development and Use of High-Speed Tool Steel. By J. M. Gledhill. (In Journal Iron and Steel Inst. pt. 2, p. 127-67, Disc. p. 168-82, Engineering, Vol. 98, p. 482-3, Disc. Engineering, Vol. 78, p. 675, American Machinist, Vol. 27, p. 1696-1700, 1730-4; Vol. 28, p. 46-51, Mechanical Engineering, Vol. 14, p. 734-6, 782-5, 851-3, 890-2, abstract in Iron Age, Vol. 74, Nov. 10, p. 12-15, in Iron Trade Review, Vol. 37, p. 83-9, Nov. 3. History, composition, effect of combination of iron and carbide with tungsten and chromium, with tungsten, with molybdenum and chromium, molybdenum and tungsten and chromium; influence of each; analyses; heat-treatment, results of tests. 7 plates.

High-Speed Tool Steel. By J. M. Gledhill. Its Manufacture and Use. (In Engineering, Vol. 97, p. 266-7. Mechanical Engineering, Vol. 13, p. 396-8, 444-6, Iron and Coal Trades Review, Vol. 68, p. 1197-1201, American Machinist, Vol. 27, p. 752-5, 788-807, abstracted in Iron Trade Review, Vol. 37, p. 44-7, April 21.) Paper read before the Coventry Engineering Society, March 4, 1904. Manufacture of crucible steel, process of converting crucible steel into high-speed steel, annealing, forging and hardening the tools, heat treatment of high-speed steel. Cutting tests.

Les Aciers Rapides a Outils. By H. Le Chatelier. (In Revue de Metallurgie Mem. 1904, p. 334-47.) Rapid steel for tools, composition, analyses and tests of high speed steels resulting from exhibition of steels made by Taylor-White process in Paris 1900.

Alloy Steels. By W. Metcalf. (In Proceedings American Society for Testing Materials, Vol. 4, p. 204-10, disc. p. 211-4, American Machinist, Vol. 27, p. 961-2.) Development and value of high-speed steel. Analyses of two brands.

High-Speed Turning. By J. Miley. In Engineering, Vol. 97, p. 146.) Abstract of paper before Leeds Ass'n. of Engrs., on progress of British manufacture of high speed steel, and on experiments to show the efficiency of the steel.

Contribution a la Theorie des Aciers Rapides. By F. Osmond. (In Revue de Metallurgie Mem. 1904, p. 348-52.) Contribution to the allotropic theory of high-speed steel.

Modern Tool Steel. By W. A. Radley. (In Mechanical Engineering, Vol. 14, p.

909.) Abstract of paper covering Huntsman, Mushet and high-speed read before the Birmingham Metallurgical Society.

Structure of High-Speed Steels. (In Engineering, Vol. 98, p. 90.) Editorial referring to papers of Le Chatelier and Osmond in Bull. Soc. Encouragement pour l'Industrie Nationale.

1905

The Types of Structure and the Critical Ranges on Heating and Cooling of High Speed Tool Steels Under Varying Thermal Conditions. By H. C. H. Carpentier. (In Journal Iron and Steel Institute, 1905, pt. 1, p. 433-73, 4 plates, 7 inserts, abstract Mechanical Engineering, Vol. 15, p. 315-16.) Concludes that the hardening of rapid tool steel involves the widening, splitting, or lowering of the critical ranges of the special alloy element, and the complete suppression of the widened, split, or lowered range by a mild quenching.

Les Aciers a Outils a Coupe Rapide. Preparation et Emploi dans les Ateliers. By J. Garnier. (In Genie Civil., 47, p. 105-8.) Tool steels for high speed Preparation and use in the shops. Composition, influence of the various constituents, preparation and treatment of rapid steels, applications, results of use of "A. W." steel.

High-Speed Tool Steels and Low Carbon Alloys. (In Iron Age, Vol. 75, p. 1733.) Use of ferrotungsten causing oxidation because of carbon impurity content, made high-speed steel of uncertain analysis.

Aciers a Outils a Coupe Rapide. By L. Guillet. (In Revue Industriele, Vol. 1905, p. 315-6, 223-4, 338-9, 358-9, Mem. Soc. Civ. de France pt. 1, p. 919-35.) P. 315. Definition, history, transformation points of carbon steels; p. 323, theory of the hardening of carbon steels. To harden a carbon tool steel, it is necessary that the hardening temperature be higher, that transformation point A^1; p. 338, composition of high-speed steel, constitution of chromium and of tungsten steels; p. 358-9, transformation points of chrome-tungsten steel an influence of the constituents; p. 368, properties treatment, results obtained at Manchester and at Birmingham.

Wolfram-und Rapidstahl. By A. Ledebur. (In Stahl und Eisen, Vol. 25, p. 768-9.) Tungsten and Rapid Steel. Theory of the influence of tungsten on self-hardening or rapid steels.

A New Hardening Furnace. (In American Machinist, Vol. 28, p. 354-5.) Brayshaw furnace for use in hardening steel. Fig. 4, heating and cooling curve of Seebohm and Dieckstahls N. C. High-Speed Steel.

1906

Quarternary Steels. By Leon Guillet. (In Journal Iron and Steel Institute, pt. 2, p. 1-141, 1 insert.) Research to systematize the use of quarternary steels, or an alloy of iron, carbon and two other added elements.

Dokter Bohlers Studien Uber den Rapid-Stahl. By F. Kick. (In Zeitung des Oesterr Ing. in Arch. Ver. v. 58, p. 267-9.) Discussion of thesis of O. Böhler on Rapid Steel before the group of machine engineers of the Vereins-Angelegenheiten.

Die Entwichlung des Schnellarbeistahles in Deuschland. By O. Thallner. (In Zeitung des Verein deut. Ing. vol. 50, p. 1690-7, 1 insert.) The development of high speed steel in Germany. The introduction of the Taylor-White Process, outline of process, chemical composition of high speed steel, influence of car-

bon, chromium tungsten, molybdenum, silicon, new knowledge on the relation between chemical composition and the hardening effect; the high speed steels in use.

1907

The Theory of High-Speed Tool Steel. By G. Auchy. (In Iron Age, Vol. 80, p. 1818-22.) Conclusions drawn from a comparison of theories of Osmond, Böhler, Le Chatelier Carpenter. Arnold, Guillet and Taylor.

The Making of High-Speed Steel Tools. By O. M. Becker. (In American Machinist, 30 pt. 1, p. 411-4.) Discusses forging, kind of furnace, heating for hardening, the oil bath, method of dipping, degree of hardness desired, tempering furnace.

An Analysis of the Evolution of Modern Tool-Steel. By H. C. H. Carpenter. (In Engineering, Vol. 83, p. 569-71, 633-4.) Current theories of hardening, the wear of tools in cutting metals, epochs in the history of tool-steels, possible future developments. Refers especially to F. W. Taylor's work on the "Art of Cutting Metals."

Sur un Nouvel Acier a Outil au Chrome. By L. Guillet. In Revue de Metallurgie Mem., Vol. 7, p. 1025-6.) A new tool-steel using chromium, microphotographs, analyses.

On the Art of Cutting Metals. By F. W. Taylor. (In Transactions A. S. M. E, Vol. 28, p. 31-279; disc. p. 280-350, 24 inserts, reprinted in one volume by Amer. Soc. Mech. Eng. translated in Revue de Metallurgie. Mem., Vol. 4, p. 39-65, 108-84, 233-336, 401-66, abstract in Engineering, Vol. 83, p. 54-5, abstract in American Machinist, Vol. 30, pt. 42-6, 215-9, 257-51.) P. 222-64 Modern high speed tools using high speed steel, chemical composition of tool-steels for high speed, discovery of high-speed steel, American Machinist extracts those parts of practical shop value.

1908

The Manufacture of High-Speed Steel. By O. M. Becker. (In Cassier's Magazine, Vol. 34, p. 291-9.) Charging of crucible, melting hole, heating and pouring of the melt, molding the ingot, annealing costs.

Possible Methods of Improving Modern High-Speed Turning Tools. By H. C. H. Carpenter. (In Transactions Manchester Association Engineers, p. 1908-9, p. 81-100, disc. pt. 111-2, 2 plates.) abstract in Engineering, Vol. 206, p. 588-9. Composition, manufacture, heat treatment of high speed tools, manufacture of tool steel in electric furnaces, welding high-speed to mild steel, summarizes possible improvements in manufacture and composition of high speed steel.

Function of Chromium and Tungsten in High-Speed Tool Steel. By C. A. Edwards. (In Journal Iron and Steel Inst., 1908, pt. 2, p. 104-32, 6 inserts, 5 plates; abstracted in Engineering, Vol. 85, p. 717; Mechanical Engineering, Vol. 21, p. 723.) Concludes that function of chromium is to form a double carbide with tungsten which imparts to these steels a very high degree of hardness and increases the resistance to tempering.

Fabrication et Usage des Outils en Acier a Grande Vitesse. (In Revue Industrielle, p. 346-50, 361-3.) Manufacture and use of tools of high speed steel. Discussion of paper by A. L. Valentine in the American Machinist includes composition of high speed steels, analyses, tools used in test, factors which in-

fluence the cutting speed, economic results, hardening high speed steel, determination of the temperature uses of high speed steel and economics which result from its use.

High-Speed Tool Manufacture. (In Mechanical Engineering, Vol. 22, p. 73) Patent of A. G. Ludwig, Berlin, of fusing high-speed steel cutting edge to shaft of ordinary steel.

A New System of Welding. (In Engineering, Vol. 85, p. 822-3.) Welding of high speed steel onto carbon steel.

La Dureté à Chaud des Aciers. By Robin. (In Revue de Metallurgie Mem., Vol. 5, p. 893-908). The hardness of steels when hot. P. 906-8. Study of high-speed steels, cooling curves.

Ueber Dreharbeit und Werkzeugstahle. By F. W. Taylor and A. Wallichs, translation. Berlin. J. Springer. Translation of "On the Art of Cutting Metals" reviewed in Zeitung des Ver. Deut. Ing., Vol. 52, p. 970.)

Making and Using of High-Speed Steel Tools. By A. L. Valentine. (In American Machinist, Vol. 30, pt. 2, p. 6-9.) Composition of metal, forging, grinding and tempering of lathes, tools and milling cutters.

1909

The Newer Sheffield Steels. By O. M. Becker. (In American Machinist, Vol. 32, pt. 2, p. 264.) Brief description of tests on new high-speed steels of W. Jessop & Sons, Ltd., Strong Twist Drill Co., and Darwin & Milner, Sheffield.

English Versus American High-Speed Steels. By E. T. Clarage. (In American Machinist, Vol. 32, pt. 1 p. 1031-2.) Explanation of the hardening of carbon steels, of high speed steels, and discussion of the progress made by American manufacturers over that of English.

Science Demands Recognition in the Arts. By E. T. Clarage. (In Iron Trade Review, Vol. 44, p. 723-4.) Arguments concerning manufacture of high-speed tool steel, disputing statement in the Engineer placing all responsibility for the success of the new steels on the workman, rather than on the steel maker.

The Special Steels in Theory and Practice. By W. Giesen. (In Iron and Steel Inst., Carnegie Scholarship Memoirs, Vol. 1, p. 1-59.) P. 44-7. The theory of the ferro-carbon of the ferro-carbon alloys and high speed cutting steels.

High-Speed Steel Patent Case. (In Mechanical Engineering, Vol. 23, p. 229-30.) Decision of the case of the Bethlehem Steel Co. vs. Niles Bement Pond Co., in which the former, who worked the patents granted to Taylor and White sought to restrain the defendants from manufacturing high-speed steel. Question depended upon the term "breaking down point."

High-Speed Steel. (In Engineering, Vol. 107, p. 174.) Decision of judge in the case on the charge of infringement of a patent for high speed steel brought by the Bethlehem Steel Co. against the Niles Bement Pond Co., in favor of latter.

Manufacture of Tools of High-Speed Steel. (In Mechanical Engineering, Vol. 23, p. 135.) Tools with working portion of high-speed steel, and the body portion of unordinary steel by process patented by Paul A. Viallon, Paris.

A New Steel. (In Engineering, Vol. 86, p. 190; American Machinist, Vol. 32, pt. 1, p. 337.) New high speed steel which is hardened in water of Jonas N. Culver of the Continental Steel Works Experiments leading up to discovery.

A New Tool Steel. (In American Machinist, Vol. 32, pt. 1, p. 241.) "Nove Superior" made by Continental Iron & Steel Co., Sheffield, Eng., as result of experiments due to the litigation over the Tavlor-White high-speed steel patents.

Tool Steel Sensation. (In Engineering, Vol. 107, p. 243-4; American Machinist, Vol. 32, pt. 1, p. 495.) Editorial on announcement of new water hardened tool steel by Prof. Arnold, its effect commercially and technically.

1910

Development and Use of the New High-Speed Steel. By W. Carter. (In Engineering, Vol. 109, p. 154-5; Mach. Engr., Vol. 25, p. 191-3; abstracted in Stahl und Eisen, Vol. 30, p. 543; abstracted in Iron Trade Review, Vol. 46, p. 480-3.) Paper before Birmingham Association of Mechanical Engineers. Development, composition, heat treatment and use of new high speed steels containing vanadium.

High-Speed Steel. By O. M. Becker. (In N. Y. McGraw-Hill Book Co. 360 pp.) The development, nature, treatment and use of high-speed steels. Problems involved in the use of high speed tools, analyses of high speed and special steels, reference table for determining cutting speeds.

High-Speed Tool Steel. By W. V. Brandt. (In Iron Age, Vol. 86, p. 1025; Mechanical Engineering, Vol. 27, p. 38.) Method of manufacture and heat treatment.

High-Speed Steel Tools. (In Iron Age, Vol. 85, p. 434-7.) Welded Tools, joining by compression, by brazing, inserted tooth saws, milling cutters and drills, compound steel reamers.

High-Speed Steel and Its Heat Treatment. By W. G. Smith. (In Mechanical Engineering, Vol. 26, p. 537-50.) Abstract of article in "The Armour Engineer" history of high-speed steel, influence of carbon, chromium, tungsten, molybdenum, silicon, method of forging, tempering, the barium chloride process, and quenching.

Tool Steel Welding. By W. F. Stanton (In Iron Age, Vol. 86, p. 987.) Method of welding a cutting edge of high speed steel onto tools made of common machinery steel.

Die Schule des Werkzeugmachers. By F. Schon. (In Hanover. M. Janecke, 156 pp.) Test-book for toolmakers, p. 120-33, high speed steel, the influences of rapid steels on the construction of tools and machines, grinding of high speed steel tools.

1911

Influence of 0.2 Per Cent Vanadium on Steels of Varying Carbon Content. By A. McWilliam, and E. J. Barnes. (In Eng., Vol. 91, p. 652-4; Iron and Steel Institute Journal, Vol. 83, p. 294-310; disc. p. 311-17.) Research on the comparative influence of vanadium on cutting steels and on chromium, tungsten, nickel and plain structural steels.

1912

The Chemical and Mechanical Relations of Iron, Vanadium, and Carbon. By J. O. Arnold, and A. A. Mead. (In Journal Iron & Steel Institute, Vol. 85, p. 213-23, disc. 227-34; Engineering, Vol. 98, p. 784-6.) Report of research to determine the composition of the carbides separated from a series of well-annealed steels containing various percentages of vanadium, the mechanical properties and the microscopical features of the alloys.

Composition of High-Speed Tool Steel. By E. T. Edwards. (In Iron Age, Vol. 89, p. 957-60; Mechanical Engineering, Vol. 29, p. 552-5.) Performance of high-speed Tool steels, of superior high speed steels, the part played by Vanadium, method of testing tool steels, tests made by author.

Microscopic Study of High-Speed Steel Tools. By F. Fettweis. (In Stahl und Eisen, Vol. 32, p. 1866-7; abstr. in Iron Age, Vol. 91, p. 189-91, 2 plates.) Carbon conditions as revealed by use of special etching solutions on chromium steel, carbon-tungsten-chromium steels, and high percentage alloy steel.

Tool Steel for the United States Navy. By L. H. Kenney. (In Transactions Soc. Nav. Arch. & Mar. Engrs., Vol. 20, p. 345-75; abstr. in Iron Age, Vol. 91, p. 839-41; Mechanical Engineering, Vol. 31, p. 401-3; Iron Trade Review, Vol. 52, p. 689-91.) P. 346-9. Specifications, development, use of tungsten tool steel, or high speed steel; p. 351-2. Selective tests on tungsten tool steel; p. 357-9. Specifications for high speed steel issued by the Navy Dept., Jan. 5, 1909; p. 362-3. Specifications for high-speed steel for U. S. Naval Academy; p. 364-75. Specifications for tool steel issued by the Navy Dept., July 20, 1911.

Manufacture of Lincoln-Williams Twist Drills. By C. L. Lucas. (In Machinery, Vol. 18, p. 515-9.) Details of process using either high-speed or carbon steels.

Die Spizialstähle. By G. Mars. Stuttgart. Ferdinand Duke. 517 pp. Special steels. p. 387, high speed steels, self-hardening, Taylor-White process, composition of various high speed steels.

Composition of High-Speed Tool Steel. By J. A. Mathews. (In Iron Age, Vol. 89, p. 1098-9.) Letter referring to paper by E. T. Edwards, Iron Age, Vol 89, p. 957, differing with Mr. Edwards as to the time of the introduction of vanadium into high-speed steels.

Vanadium in High-Speed Steel. (In Machinery, Vol. 18, p. 837.) Effect of varying amounts of vanadium from 0.2-1.0 per cent, on cutting speed of high-speed steel, figures given by American Vanadium Co.

1913

Modern Tool Steels and High-Speed Tool Alloys. By G. S. Armstrong. (In Engineering Magazine, Vol. 45, p. 833-42; Vol. 46, p. 63-76. 194-200, 400-15, 931-42.) P. 883-42, theory of hardening, factors conducive to cutting speed, development of tool steels and alloys. P. 63-76, processes of manufacture, mechanical treatment, machinery and equipment used. P. 194-200, application of carbon and alloy steels to specific uses. P. 400-15, heat-treatment, furnaces, baths and pyrometers. P. 931-42, machine-tool operation at high cutting speeds, inserts.

Recent Advances in Scientific Steel Metallurgy. By J. O. Arnold. (In Engineering, Vol. 95, p. 162, Mechanical Engineering, Vol. 31, p. 153-4.) Paper read before the Royal Institution, traces the development of Mushet high-speed and vanadium high-speed steels. Table gives comparative cutting powers of Huntsman-low-grade, and high-grade high-speed steels.

Structure des Aciers et Modifications Accompagnant les Traitments Thermique. By De Nolly. (In Bull. Soc. l'Ind. Min., Vol. 4, p. 371-82. 8 plates.) Structure of steels and modifications accompanying the heat treatment. Point of transformation, theory of hardening, use of microscope, dilation curves of a high-speed steel, heated to 850 degrees, 7050 degrees Cent.

Die Fortschritte Deutscher. (Stahl und Eisen, Vol. 33, p. 1196-1204, 1363-4, 1403.) Discussion on Schlesinger's paper, "The progress of German Steel Works in high alloyed rapid steels," by Poldihutte, Schlesinger, E. Kothny, and the steel firms involved.

Composition of High-Speed Tool Steel. By E. T. Edwards. (In Iron Age, Vol. 89, p. 937-60; Mechanical Engineering, Vol. 29, p. 552-5.) Performance of high speed steels of superior high-speed steels, the part played by vanadium, method of testing tool steels, tests made by author.

Die Fortschritte Deutscher Stahlwerke bei der Herstellung Hochlegierter Schnollarbeitsstahle. By G. Schlesinger. (In Stahl und Eisen, Vol. 33, p. 929-39; abstr. in Iron Age, Vol. 92, p. 33.) The progress in German steel works of the production of high-alloyed rapid working steels, considering especially the effect of cobalt. Tests on cobalt high speed tool steel at Royal Technical High School, Berlin.

1914

Behavior of Iron in Some Alloys. (In Iron Trade Review, Vol. 55, p 526, 5606. Abstract of papers and discussion on "The Chemical and Mechanical Relations of Iron, Tungsten, and Carbon, and of Iron, Tungsten, and Nickel" by A. A. Read and J. O. Arnold before the Institutions of Mechanical Engineers.

Built-Up High-Speed Steel Cutting Tools. (In Iron Age, Vol. 93, p. 1124-5). Process developed by Adolph Rosner of Bridgeport, Conn., of welding high-speed steel to low-grade carbon steel. Costs.

Etude sur les Propietes Generales des Aciers a Outils. By Denis. (In Revue de Metallurgy Mem., Vol 11, p. 569-669; abstr. in Journal Amer. Spc. Mech. Eng., Vol. 36, p. 0164-6.) Investigation into the general properties of tool steel, discussing the method of tests and heat treatment of various kinds of tool steels, detailed data of the tests, and conclusions from this data.

Note on the Transformations of Steels. By H. De Nolly and L. Veyret. (In Journal Iron and Steel Inst., Vol. 90, p. 165-80; Engineering, Vol. 98, p. 631-3.) Discussion of the carbide theory, the allotropic theory, and a theory of the dissociation of the carbide accompanied by the solid solution in the iron, of the carbon liberated by this association, proposed by the authors, and illustration by curves of critical points of high speed tool steel.

Ueber die Analyse von Schnelldrehstahl. By F. Fettwies. (In Stahl und Eisen, Vol. 34, p. 274 and 275.) On the analyses of high-speed steel. Presented before the chemical committee of the Vereins deutscher Eisenhuttenleute. Discussion.

Gegossene Schnelldrehstahle. (In Stahl und Eisen, Vol. 34, p. 1306-7.) Casting high-speed steels, forging, tempering to tools.

Qualques Essais de Duree avec des Aciers Rapides. By R. Poliakoff. (In Werkstattstechnik, Feb. 1, 1914, abstr. in Bull Soc. D'Encour., Vol. 121, p. 659-60.) Some tests on durability of high speed steels. Table giving chemical composition of steels tested.

Welding High-Speed to Ordinary Steel. (In Iron Age, Vol. 4, p. 152.) It is necessary to prevent the weld from cooling between the time it is made and the annealing. Temperature should not drop below 1200 degrees Fahr.

1915

Experiments on the Corrosion of Molybdenum. By L. Aitchison. (In Journal American Chemical Society, Vol. 107, p. 1531-8.) Addition of molybdenum to pure carbon steel results in a definite increase of corrosion until very high percentages are reached.

The Chemical and Mechanical Relations of Iron, Cobalt and Carbon. By J. O. Arnold and A. A. Read. (Inst. Mech. Engrs. 1915, p. 629-51; Engineering, Vol. 99, p. 362-4, disc. p. 346-8.) Theory microphotograps and tests referring especially to the carbides of cobalt

Failures of High-Speed Steels. By G. J. Brunelle. (In Railway Age Gazette Mech. Ed. p. 89, 369-70; Mechanical Engineering, Vol. 36, p. 238-40.) Failures due to forging, heat-treating, grinding and abuse.

The Thermo-Electric Properties of Special Steels. By E. L. Dupuy and A. M. Portevin. (In Journal Iron and Steel Institute, Vol. 91, p. 306-35.) Tests on nickel, chromium, manganese, aluminum, silicon, tungsten, molybdenum steels.

Manufacture and Uses of Alloy Steels. By H. D. Hibbard. (In U. S. Bureau of Mines Bull. 100, 77 pp. Extract Mechanical Engineering, Vol. 38, p. 4-6, 31-2.) P. 53-67. High speed steels including manufacture, composition, effect of carbon, chromium, tungsten, molybdenum, cobalt, copper, sulphur and phosphorus in high speed steel, heat-treatment, theory-patents and bibliography.

High-Speed Steel Alloys. (In Engineering, Vol. 102, p. 509-10.) Editorial on the Ed., Vol. 89, p. 590.) Welding high-speed steel tips on shanks or holders made of axle or tire steel.

1916

German High-Speed Steel. (In Iron Age, Vol. 98, p. 1111, quotations from Elektrotechnische Rundschau.) Composition of high speed steel for lathe tools, brief outline of hardening process.

High-Speed Steel Alloys. (In Engineering, Vol. 102, p. 509-10.) Editorial on the supply of tungsten for use in making high speed steels.

High Speed Steels Without Tungsten. (In Iron Age, Vol. 97, p. 1527.) Darwin and Milner steel containing neither tungsten, molybdenum, cobalt or vanadium, and German tungstenless high-speed steel of Richard Lindenberg Steel works at Remshied.

The Transformations of Special Steels at High Temperatures. By K. K. Honda, Tawara and H. Takagi. (In Journal Iron and Steel Inst., Vol. 93, p. 224-54, 3 plates. Investigation on carbon steels, D. S. W. Steel, Ultra Capital Seebohm, New Capital Seebohm, Bohler Super-Rapid Novo, and Becher Diamond Steels.

Molybdenum: Its Ores and Their Concentration. By F. W. Horton. U. S. Bureau Mines Bull. 111., 132 pp. P. 21-25. Molybdenum steels, use of molybdenum in tool steels.

New High-Speed Steels. (In Mechanical Engineering, Vol. 37, p. 394-5.) Editorial announcing that Darwin & Milner had discovered an alloy substitute for high-speed steel that contains neither tungsten, cobalt, molybdenum or vanadium.

The New British High-Speed Steel. (In Iron Age, Vol. 98, p. 55.) "Reactol" steel contains neither tungsten nor cobalt, and requires neither forging, hardening nor tempering, produced in Sheffield.

Producing Lathe Tools Autogenously. (In Iron Age, Vol. 97, p. 902; Mechanical Engineering, Vol. 37, p. 372.) System of welding high-speed to carbon steel at the Topeka shops of the Atchison, Topeka, and Santa Fe Railway Co.

A New High-Speed Tool Steel. (In Engineering, Vol. 101, p. 510.) New steel containing neither tungsten, molybdenum or cobalt, cast to desired form, ground on an emery-wheel (dry), finished on a wet grindstone, and is ready for use, made by Darwin and Milner, Sheffield.

Reclaiming High-Speed Steel. (In Iron Age, Vol. 97, p.1032) Onondaga Steel Co., Syracuse, N. Y., takes odds and ends of high speed steel and forges them into tool bits.

Uranium in Tool Steel. (In Iron Age, Vol. 97, p. 952; Iron Trade Review, Vol. 59, p. 4771. Comparative tests of uranium and other high-speed steels, by Standard Chemical Co., Pittsburgh.

Welded High-Speed Steel Cutting Tools. (In Iron Age, Vol. 97, p. 700.) Brief description of incandescent welding of high-speed steel to hot and cold rolled steel bars and to ordinary tool steel by the Westinghouse Electric and Manufacturing Co.

1917

Cobalterom, the New Steel Alloy. (In Engineering, Vol. 104, p. 22.) New high-speed steel alloy which does not contain tungsten, discovered and patented by Darwin & Milner. Maximum heat necessary for hardening is only 1000 degrees Cent. Cools naturally in still air.

The Penetration of the Hardening Effect in Chromium and Copper Steels. By L. Grenet. (In Journal Iron and Steel Institute, Vol. 95, p. 107-14, disc. p. 115-7, abstr. in Iron Age, Vol. 100, p. 808-9.) Effect of chromium, copper and nickel on the penertation of the hardening.

Emploi des Outils en Aciers Moule Rapide. By L. Grenet. (In Revue de Metallurgie Memoirs, Vol. 14, p. 547-50, abstr. in Iron Age, Vol. 101, p.1204.) Cast high-speed tool steels, tests on extra hard, hard, and normal steel at the Firming steel works.

A High-Speed Tool Steel Patent Action. (In Engineers, Vol. 123, p. 412.) Action for the revocation of British Pat. No. 27838 of 1912, granted to the Stahlwerk Becker Aktiongesellschaft of Krefehd-Willich, Germany, for a steel containing cobalt.

Two New High-Speed Steel Tools. (In Iron Age, Vol. 100, p. 655.) Abstract of U. S. Pat. 1,233,118 by James H. Parker for tungsten-chromium vanadium steel and of U. S. Pat. 1,233,862 of Radclyffe Furnace for addition of cobalt and tungsten to high-speed tool steel containing tungsten, chromium, and vanadium to increase cutting efficiency.

1918

Liquid Steel. By D. Carnegie. 2nd. Ed. N. Y. Longsman Green and Co., 526 pp. P. 106-9, cost of crucible steel for carbon and high speed tools. p. 112-5, composition of high speed steels charges.

Cobalt High-Speed Steel Not a German Discovery. (In Iron Age, Vol. 101, p. 321.) Discussion and quotation from the Ironmonger concerning the relocation of

the German patent on cobalt tool steel, as result of decision of British court in the action brought by the Dannamore Steel works of Sheffield.

Quelques Observations Sur "Le Stellite." By L. Guillet and H. Godfroid. (In Revue de Metallurgie, Vol. 15, p. 339-46, abstr. in Iron Age, Vol. 102, p.1584-5.) Some observations on stellite including comparison made of the variation in hardness at different temperature of stellite and a superior quality of high-speed steel.

How Small Tools Were Made Quickly. (In Iron Trade Review, Vol. 62, p. 858-9.) Method for making high-speed steel reamers developed in Jackson, Tenn., shop of Illinois Central Railroad.

The New Cobalt Tool Steel. (In Iron Age, Vol. 91, p. 1477.) Mention of a detailed report of extensive comparative tests of the new German cobalt steel with other tool steels, sent out by the Becker Steel Co. of America.

New High-Speed Tool Steel High in Cobalt. (In Iron Age, Vol. 101, p. 743.) U. S. Pat. 1, 233,118 of J. H. Parker and B. H. Delong of New high-speed alloy steel containing 30 per cent cobalt, 2 per cent vanadium, 3.5 per cent chromium, 12 per cent tungsten, 0.35 per cent carbon.

Iron and Steel. By E. Oberg and F. D. Jones. (In N. Y. Industrial press. 328 pp.) P. 276-97, High Speed Steel, includes origin, Taylor-White process of heat-treatment production of high speed steel, effect of different elements in high speed steels, hardening practice, tempering, annealing, uses.

Molybdenum Seel Versus Gun Erosion. By M. Okochi, M. Kanima, N. Sato. (In Journal College of Eng. Tokyo Imperial Univ., Vol. 9, p. 153-95, Journal Soc. Mech. Engr. Tokyo, Vol. 22, p. 1-44, No. 54.) Experimental determination of modulus of elasticity, modolus of rigidity, Brinell hardness number, thermal dilation, thermal conductivity, and magnetization at high temperatures of specimens of gun steel, nickel steel, nickel-molybdenum steel and tungsten steel.

The Salvaging of High-Speed Steel. (In Iron Trade Review, Vol. 62, p. 845-8.) Practical methods for conserving this valuable material, resmelting, building up tools, electric butt-welding tools.

Resherches sur l'Acier a Couple Rapide Faites au Labora toire du Harvard. By M. Yatesevitch, translated by H. Herbert. (In Revue de Metallurgie Memoirs, Vol. 15, p. 65-109, bibliography 109-115.) Research on high-speed steel made at the laboratory at Harvard. Study on the "Dreadnaught" steel of the Halcomb Steel Co., on determination of the modification in structures and caused by heating and cooling under various conditions, microscopic study of heat-treatment, relation between hardness and heat-treatment.

1919

The Manufacture of Working of High-Speed Steel. By J. H. Andrew and G. W. Green. (In Journal Iron and Steel Institute, Vol. 99, p. 305-26, disc. p. 337-44, 6 plates, 1 insert; abstr. Iron Age, Vol. 104, p. 703-7; Engineering, Vol. 107, p. 688-70.) Practical application of scientific methods to high-speed steel practice, following through the steel from the state of ingot to the finished tool.

The Molecular Constitutions of High-Speed Tool Steels and Their Correlation with Lathe Efficiencies. By J. W. Arnold and F. Ibbotson. (In Journal of Iron and Steel Institute, Vol. 99, P. 407-28, disc. p. 429-35, 2 plates, 1 insert; abstr. In Iron Trade Review, Vol. 64, p. 1419 to 1421.) The Chemical constitutions of

high-speed steels, correlation of the chemical and micrographic analyses with lathe efficiencies of the series. Note on surface tension effects in high-speed steels by F. C. Thompson.

Metallic Alloys. By G. H. Gullever. 3rd Ed. London, C. Griffin & Co. 410 pp. P. 329, brief mention of high speed tool steel under quaternary steels.

Manufacture and Use of Alloy Steels. By H. D. Hibbard. J. Wiley & Sons, N. Y., 96 pp. P. 68-87, manufacture, composition, heat treatment, theory, testing, using and patents of high speed steels. Bibliography.

Favorable Results from Cobalt. By N. B. Hoffman. (In Proceedings Amer. Soc. Test. Mat., Vol. 19, p. 177-179; Iron Age, Vol. 104, p. 21-2.) Discussion of Dr. Mathew's paper. Analyses and tests of high-speed steel containing cobalt.

The Properties of High-Speed Steel. By G. J. Horvitz. (In Journal Amer. Steel Treaters' Soc., Vol. 2, p. 342-48; abstr. Iron Age, Vol. 103, p. 1711-4.) Composition, crucible and electric processes of manufacture, hardening, heat treatment, theory of hardening, physical properties. 13 microphotographs.

Davidson Process of Casting Formed Tools. By J. F. Johnson. (In Bull. 146, A. I. M. E., p. 353-60; abstr. in Iron Age, Vol. 103, p. 481-3.) A cast tool steel claimed to have the properties of a high speed steel.

Manufacture of Modern High-Speed Steel. By J. A. Mathews. (In Proceedings Amer. Soc. Testing Materials Proc., Vol. 19, p. 141-56; Iron Age, Vol. 104, p. 17-20; abstr. in Metaux, Alliazes et Machines, Vol. 13, p. 8, No. 2.) Evolution from air-hardening steel, effects of chromium and tungsten, detection of overheating, recent disc of vanadium.

High Cobalt Content and High Drawing Temperatures. By J. H. Parker. (In Proceedings Amer. Soc. Test. Mat., Vol. 19, p. 159-61; Iron Age, Vol. 104, p. 201.) Discussion of Dr. Mathew's paper, concerning use of vanadium and cobalt and of the value of chemical analyses.

Specifications for High-Speed Steels. By R. Poliakoff. (In Iron Age, Vol. 103, p. 827-9.) Summarizes opinions of four European manufacturers on thirteen requirements to be considered in working out specifications for delivery, dealing especially with the test tools.

Standardizing of Practice Important. By. E. W. Rettew, (In Proceedings Amer. Soc. Test. Mat., Vol. 19, p. 176-7; Iron Age, Vol. 104, p. 21.) Table of limits and desired analysis resulting from study of high speed steel analyses.

Physical Properties of High Chrome Steel. By L. R. Seidell and G. J. Horbitz. (In Iron Age, Vol. 103, p. 291-4.) Relation between hardness and double carbides in solutions, maximum tensile strength and ductility.

Tungstenless Tool Steel. (In Ironmonger, Vol. 169, p. 86-87, Dec. 27; Raw Material, Vol. 2, p. 60-1.) Use of Prof. J. O. Arnold of 6 per cent molybdenum for 18 per cent tungsten in high speed steel, with one-fourth per cent vanadium as a molybdenum stabilizer.

1920

The Properties of Water Quenched Vanadium-Molybdenum High-Speed Steel. By J. O. Arnold. (In Engineering, Vol. 128, p. 480.) Properties of a high-speed steel, patented under a sealed patent in September, 1919, substituted for tungsten, molybdenum associated with a little over 1 per cent of vanadium, the key

element of the chemical composition. The vanadium appears to stabilize the variable properties of molybdenum steel, and to prevent cracking during the water-hardening operation.

On the Structural Constitution of High-Speed Steel Containing Chromium and Tungsten and the Effect of these Elements on Its Hardening and Tempering. By K. Honda, and T. Murakami. (In Science Report of the Tokoku Imperial University, Vol. 9, p. 143-68, 7 plates; Journal Iron and Steel Inst. Reprint 15.) Object of research is to ascertain the structural constitution of high-speed steel, the change of these constituents during heating and cooling, the effect of these constituents upon hardening and tempering.

Reclaiming and Using Broken High-Speed Tools. By J. A. Hope. (In Can. Mach., Vol. 23, 312-313.) Construction of remelting furnace, crucibles, molds, drawing out of ingot procedure in melting; costs.

Making Forged High-Speed Twist Drills. By J. V. Hunter. (In American Machinist, Vol. 52, p. 719-22.) Methods used by Kettler, Elliot Erection Co., Chicago.

A Comparative Test Upon High-Speed Steels. By A. J. Langhammer. (In Chemical and Metallurgical Engineering, Vol. 22, p. 829-32, p. 889-92, 939-42; American Machinist, Vol. 52, p. 979-82.) P. 829. Current sales practices, general review of tool steel, high-speed steel, stellite, influence of chemical composition, inconsistency of recommended heat-treatments, table of marker's recommendations for treating lathe and planes tools. P. 889, conditions entering into the testing of a tool for cutting as listed by Taylor are discussed, method of eliminating most of the variables from a comparative test for the efficiency of several brands of commercial tool steel, p. 939. Detailed description of tests on 16 high-speed steels, with data as to performance, chemical composition, heat-treatment and hardness.

High-Speed Steel Drop Forgings for Milling Cutters and Special Tools. By A. F. MacFarlan. (In Journal American Steel Treaters Soc., Vol. 2, p. 279-87.) Advantages claimed for drop-forged high speed tool blanks are more homogeneous structure, lower machine cost, lower scrap losses, time saved in making a tool, elimination of physical defects, and increased production per tool.

The Manufacture of High-Speed Steel in the Electric Furnace. By R. C. McKenna. (In American Electrochemical Society Reprint 31, p. 417-23.) Details of charging, melting, slagging, teeming, forging heat treatment are discussed and the various important points in the electric furnace practice given.

Tool Steels Influence on Progress and Prosperity. (In Raw Material, Vol. 2, p. 54-59.) Describes alloy steels intermediate between carbon and high-speed steels.

The New High-Speed Steel. By L. Aitchison. (In Autocar, Vol. 44, p. 56-7.) History of high speed steel, new formula using molybdenum of Prof. Arnold, costs.

Salvaging High-Speed Steel Scrap. By S. S. Buckley. (In Railway Mechanical Engineer, Vol. 94, p. 290.) Outlines the method of salvaging high speed steel and describes the spark test for testing the scrap.

High-Speed Cast Steel Tools from the Electric Furnace. By S. H. Bannell. (In Iron Age, Vol. 106, p. 1258-9.) Outlines the practice of the U. S. High Speed Steel & Tool Co. in making tools ready for use in any desired shape.

Production of Tool Steel. By F. R. Daniels. (In Machinery, Vol. 27, p. 42-6.) Outlines the processes employed in the steel mill of the Ludlum Steel Co., Watervliet, which manufactures tool and special alloy steels.

Forging of High-Speed Steels. By A. H. Kingsbury. (In Iron Age, Vol. 105, p. 328-9.) Discusses temperature limits, their effects on cracking and gives recommendations for successful results.

Alloy-Steel Development. By J. W. Marshall. (In American Machinist, Vol. 52, p. 817-8.) Outlines the history of the development of high speed steel.

Manufacture of High-Speed Steel in the Electric Furnace. By R. C. McKenna. (In Transactions Amer. Electrochemical Soc., Vol. 37, p. 319-25, discussion 325-8.) A detailed description from the manufacturer's standpoint of the advantages of the electric furnace process over any other way of making high-speed tool steel. Details of charging, melting, slagging, teeming, forging, heat-treatment, etc. are discussed.

Manufacturing High Speed Steel. By R. C. McKenna. (In Iron Trade Review, Vol. 66, p. 148-9.) Manufacture of high speed steel requires the highest degree of skill and knowledge throughout the process. Describes the process of manufacture and precaution that must be taken.

Oberschleische Eisen-Industrie. Chrom, Wolfram and Molybdän enthaltender Schnelldrehstahl mit Zusatz von Kobalt. (Chrome tungsten and molybdenum high-speed tool steel with cobalt as a substitute.) (In Stahl und Eisen, Vol. 40. I p. 128.) German patent 300765, class 18b, Feb. 19, 1916. A considerable portion of the tungsten can be replaced by molybdenum and cobalt.

Schnellasbeitsstahl (High-Speed Steel). By Stahlwerke Rich Lindenberg. (In Stahl und Eisen, Vol. 40 I, p. 327.) German patent 300731, class 18b, Feb. 27, 1916. This steel contains 0.6-1.2 per cent carbon, ½ per cent manganese, 0.1-0.3 silicon, 3-10 per cent chromium, 1-5 per cent cobalt. May also contain 0.15-2.0 per cent vanadium.

Tungstenless Tool Steel. (In Iron Age, Vol. 105, p. 339.) Molybdenum is used instead of tungsten and cobalt and vanadium are added as stabilizers. This steel was invented by Dr. Arnold.

Two Carbon Tool Steels, One Made from Detinned Scrap. (In Iron Age, Vol. 105, p. 1277.) One of these steels was made from Swedish base in a crucible, and the other was made from detinned scrap in an electric furnace. Tests showed but little difference between the two.

1921

American Practice in High-Speed Steel Manufacture. By A. H. d'Arcambal. (In Chemical and Metallurgical Engineering, Vol. 25, p. 1097-9.) The impressions of a tool steel manufacturer on visiting several plants. Emphasizes the importance of pure raw materials and metallurgical control of all steps in the process.

Drill Steel from Hollow Ingots. By P. A. E. Armstrong. (In Chemical and Metallurgical Engineering, Vol. 24, p. 960-4.) A definite effort to produce hollow drill steel with a decarbonized interior surface by inserting a mild steel tube in the ingot mold, plugging it with stand, casting the steel and subsequently rolling to size.

Constitution of Chromium Tungsten Steels. (In Chemical and Metallurgical En-

gineering, Vol. 24, p. 791-3.) Recent Japanese work throwing light, upon the complex reactions giving self-hardening and red-hardness properties to modern high-speed steels.

Metallurgy of High-Speed Steel. By D. M. Giltinan. (In Transactions American Society for Steel Treating, Vol. 1, p. 716-26.) An account of the development of high-speed steel and some theories of self-hardening.

Electric Furnace Tool Steel Qualities. By W. J. Green and S. S. Green. (In Iron Age, Vol. 108, p. 669-71.) Takes up the vital considerations in practice to insure regularity, role of purity of stock, sample specifications and alloy or reinforced steels.

Features of Electric Tool Steel Practice. By W. J. Green and S. S. Green. (In Iron Age, Vol. 108, p. 1001-4.) Standardized shop practice necessary, large ingots recommended, and top pouring is preferred.

Failure of Metals Through the Action of Internal Stress Irregularities With Special Reference to Tool Steel. By J. N. Greenwood. (In Engineering, Vol. 111, p. 535-7.) Abstr. of paper before Faraday Soc. Takes up the origin and effect of internal stresses, the properties of metals with regard to resistance to failure, and the hardening and tempering of carbon steels.

Manufacture of High-Speed Steel. By Felix Kremp. (In Official Proceedings, Central Ry. Club, Vol. 29, p. 1042-6, discussion, p. 1046-51.)

Recent Work on Chromium Tungsten Steel. (In Chemical and Metallurgical Engineering, Vol. 24, p. 573-5.) Reviews literature on chromium-tungsten steels especially the work of Japanese investigators. Describes methods of magnetic analysis.

Effect of Tungsten Content on the Specific Gravity of High-Speed Steel. By A. S. Townsend. (In Transaction Amer. Soc. Steel Treating, Vol. 2, p. 133-8.) Specific gravity of high speed steel increases with tungsten content.

High-Speed Steel Manufacture in Sheffield. By P. M. Tyler, (In Iron Age, Vol. 107, p. 371-4. Discussion by Hodson, p. 721-2.) Gives present practice, prices, sources of raw material. Wages are lower than in America.

How to Make the Most Out of High-Speed Steel. By A. J. Wilson. (In Transactions Amer. Soc. Steel Treating, Vol. 1, p. 436-40.) Tells of ways in which the life of high speed steel tools was prolonged.

1922

Preparing Tool Steel at the Mill. By A. W. F. Green. (In Transactions Amer. Soc. Steel Treating, Vol. 2, p. 274-87.) Takes up the effects of proper finishing temperatures in the hammer shop and rolling mill on the steel and the normalizing and annealing of the product.

Crucible and Electric Tool Steel. By W. J. Green and S. S. Green. (In Iron Age, Vol. 109, p. 201-5.) Discusses the difference between crucible and electric tool steel, and compares the operating conditions in detail.

HEAT-TREATMENT OF HIGH-SPEED STEEL

1900

Steel for High-Speed Cutting Tools. (In Mechanical Engineering, Vol. 6, p. 685-6.) Editorial concerning the patent specifications of the Taylor-White process.

The Taylor-White Process of Treating Steel. (In Mechanical Engineering, Vol. 6, 6. 699-702, No. 17; American Machinist, Vol. 23, p. 1169-70.) Reprint of the British patent 10788 of 1900.

1903

The New Tool Steel and Its Effect on Machine Shop Methods. By C. T. King. (In Wisconsin Engineer, Vol. 7, p. 255-61.) Development of tool steel, discovery of high-speed steel, cause of change in steel structure by heat-treatment.

High-Speed Steel. By H. W. Rushmer. (In Iron Trade Review, Vol. 36, p. 50-1, Sept. 24, American Machinist, Vol. 26, p. 1270-81.) Discovery of Taylor-White process, superiority of new steels, annealing, forging and tempering high speed steels.

Zur Kenntnis der Theorie der Sogenannten Rapid-und Naturhartern Stahle. By J. Spuller. (In Chem. Zeitung, Vol. 27, p. 165-6.) On the knowledge of the theory of the rapid and self-hardening steels, considers that as the carbon of the iron carbide becomes mobile at about 1000 degrees Cent. it passes out of the iron carbide and forms chrome carbide, tungsten carbide, it playing a most important part in imparting hardness to the steel.

The Taylor-White Process of Treating Tool Steel. (In Journal Franklin Institute Vol. 155, p. 127-37, Bulletin, Society Encouragement pour l'Industries Nationale, Vol. 903, p. 293-8.) Report of the committee on the inventions of Maunsel White and F. W. Taylor. Development and application of the process.

1904

High-Speed Tool Steels. By W. Brown. (In American Machinist, Vol. 27, p. 737-8.) Heat treatment of hardening of tools; rate of speed desirable.

Beitrag zur Kenntnis und Theorie des Schnelldrehstahls. By H. Eckardt. (In Stahl und Eisen, Vol. 24, p. 611-3, extract in American Machinist, Vol. 27, p. 1080-1.) Contribution to the knowledge and theory of high-speed steels. Discussion of the properties of the Taylor-White and European steels made after the Taylor-White process. Deals especially with the cutting and high-speed qualities.

The Development and Use of High-Speed Tool Steel. By J. M. Gledhill. (In Journal Iron and Steel Inst. pt. 2, p. 127-67, disc. p. 168-82, Engineering Vol. 98, p. 482-3, disc. Engineering, Vol. 78, p. 675, American Machinist, Vol. 27, p. 1696-1700, 1730-4, Vol. 28, p. 46-51, Mechanical Engineering, Vol. 14, p. 734-6, 782-5, 851-3, 890-2, abstr. in Iron Age, Vol. 74, Nov. 10, p. 12-15 in Iron Trade Review, Vol. 37, p. 83-9, Nov. 3. History, composition, effect of combination of iron and carbide with tungsten and chromium, with tungsten, with molybdenum and chromium, molybdenum and tungsten and chromium; influence of each; analyses; heat-treatment, results of tests. 7 plates.

High-Speed Tool Steel. By J. M. Gledhill. Its Manufacture and Use. (In Engineering, Vol. 97, p. 266-7, Mechanical Engineering, Vol. 13, p. 396-8, 444-6, Iron and Coal Trades Review, Vol. 68, p. 1197-1201, American Machinist, Vol. 27, p. 752-5, 788-807, Abstr. in Iron Trade Review, Vol. 37, p. 14-7, April 21.) Paper read before the Coventry Engineering Society, March 4, 1904. Manufacture of crucible steel, process of converting crucible steel into high-speed steel, annealing, forging and hardening the tools, heat treatment of high-speed steel, cutting tests.

High-Speed Tool Steels. (In Machinist Vol. 10, p. 534-5.) Practical suggestions for hardening the new steels.

Contribution a la Theorie des Aciers Rapides. By F. Osmond. (In Revue de Metal lurgie Memoirs 1904, p. 348-52.) Contributions to the allotropic theory of high-speed steel.

The Practical Handling of High-Speed Steels. (In Iron Age, Vol. 74, Oct. 6, p. 7-8.) Treatment of high speed tools, heating, hardening, quenching in fish oil, drawing, costs.

Heat Treatment Experiments with Chrome-Vanadium Steel. By H. R. Sankey and J. K. Smith. (In Inst. Mech. Engrs. pt. 3-4, p. 1235-82, disc. 1283-1317, plates 147-59, abstr. and disc. in Engineering, Vol. 95, p. 615-7.) Detailed tests on chrome vanadium spring steel.

Structure of High-Speed Steels. (In Engineering, Vol. 98, p. 90.) Editorial referring to papers of Le Chatelier and Osmond in Bulletin Society Encouragement pour l'Industrie Nationale.

High-Speed for Finishing. By P. Wesley. (In American Machinist, Vol. 27, p. 529-30.) Result of experimenting on use of high-speed steel tool for finishing. Tool was heated till the point burnt off, and cooled in the air blast.

1905

The Types of Structure and the Critical Ranges on Heating and Cooling of High-Speed Tool Steels Under Varying Thermal Conditions. By H. C. H. Carpenter. (In Journal Iron & Steel Inst., 1905, pt. 1, p. 433-73, 4 plates, 7 inserts abstr. Mechanical Engineering, Vol. 15, p. 315-16.) Concludes that the hardening of rapid tool steel involves the widening, splitting, or lowering of the critical ranges of the special alloy element, and the complete suppression of the widened, split, or lowered range by a mild quenching.

Les Aciers a Outils a Coupe Rapide. Preparation et Emploi dans les Ateliers. By J. Garnier. (In Genie Civil, Vol. 47, p. 105-8.) Tool steels for high speed. Preparation and use in the shops. Composition influence of the various constituents, preparation and treatment of rapid steels, applications, results of use of "A. W." steel.

Note sur la Trempe de l'Acier. By L. Grenet. (In Bulletin, Soc. Ind. Min., Vol. 4, p. 973-99.) Note on the hardening of steel, p. 987 chrome-tungsten and high-speed steels. Considers that hardening is caused by a transformation in the cooling to a lower temperature and not by the conservation of a stable state formed at a high temperature.

Aciers a Outils a Coupe Rapide. By L. Guillet. (In Revue Industrielle, Vol. 1905, p. 315-6, 323-4, 338-9, 358-9; Memoirs Soc. Civ. de France pt. 1, p. 919-45.) P. 315, definition, history, transformation points of carbon steels; p. 323, theory of the hardening of carbon steels. To harden a carbon tool steel, it is necessary that the hardening temperature be higher, than transformation point A'; p. 338 composition of high-speed steel, constitution of chromium and of tungsten steels; p. 358-9, transformation points of chrome-tungsten steel an influence of the constituents; p. 368, properties, treatment, results obtained at Manchester and at Birmingham.

A New Hardening Furnace. (In American Machinist. Vol. 28, p. 354-5.) Brayshaw furnace for use in hardening steel. Fig. 4, heating and cooling curve of Seebohm and Dieckstahls N. C. High-speed steel.

1906

Tempering and Cutting Tests of High-Speed Steels. By H. C. H. Carpenter. (In Journal Iron and Steel Institute 1906, pt. 3, p. 377-96, 5 plates, abstr. in Engineering, Vol. 82, p. 300-4, Stahl und Eissen, Vol. 26, p. 1018-9, transl. in Metallurgie, Vol. 3, p. 511-22, abstr. Mechanical Engineering, Vol. 18, p. 164-70.) Report of research to ascertain whether the temperature at which high-speed steels soften can be pushed higher than 700 degrees Cent.

Quaternary Steels. By L. Guillet. (In Journal Iron and Steel Institute pt. 2, p. 1,141, 1 insert.) Research to systematize the use of quaternary steels, or an alloy of iron, carbon and two other added elements.

Process of Hardening High-Speed Steel. (In Mechanical Engineering, Vol. 17, p. 504.) Patented process of S. N. Brayshaw, heating the steel up to a very high temperature, soaking it in a high temperature bath from 900 degrees to 950 degrees C, quenching it in a bath at 100 degrees C.

Die Entwichlung des Schnellarbeitstahles in Deutschland. By O. Tahallner. (In Zeitung des Verein deut. Ing., Vol. 50, p. 1690-7, 1 insert.) The development of high-speed steel in Germany. The introduction of the Taylor-White Process, outline of process, chemical composition of high-speed steel, influence of carbon, chromium tungsten, molybdenum, silicon; new knowledge on the relation between chemical composition and the hardening-effect the high-speed steels in use.

1907

The Theory of High-Speed Tool Steel. By G. Auchy, (In Iron Age, Vol. 80, p. 1818-22.) Conclusions drawn from a comparison of theories of Osmond, Bohler, Le Chatelier, Carpenter, Arnold, Guillet and Taylor.

The Making of High-Speed Steel Tools. By O. M. Becker. (In American Machinist, 30 pt. 1, p. 411.) Discusses forging, kind of furnace, heating for hardening, the oil bath, method of dipping, degree of hardness desired, tempering furnace.

High-Speed Tool Steel. By H. C. H. Carpenter. (In Iron Age, Vol. 79, p. 822 4.) Contribution to the discussion of F. W. Taylor's "On the Art of Cutting Metals" and reprinted from the Proceedings of the American Society of Mechanical Engineers. Includes corrections red hardness, structure of steel, the heat at which tools cut best, other hardening agents than carbon, the action of chromium and tungsten, classification of types cutting tools, and the question of maximum temperature.

The Hardening of High-Speed Steel Taps. By L. Guillet. (In Iron Age, Vol. 80, p. 368.) Process tested and recommended by Wheelock, Lovejoy & Co., with the use of a barium chloride bath in a standard gas hardening furnace.

Tempering High-Speed Steel. By. G. Lindsay. (In Mechanical Engineering, Vol. 19, p. 75.) Abstract of paper before the American Master Blacksmith's Ass'n. describing the use of a lead bath.

Annealing and Hardening High-Speed Steel. By C. W. Scott. (In American Machinist, Vol. 30, pt. 1, p. 322-3) Recommends annealing in cast iron box, heat to 800 degrees Cent. for at least 5 hours, raise heat to 900 degrees Cent., shut off fire, close door, remove steel after 12 hours.

Annealing High-Speed Steel. By C. W. Scott. (In American Machinist, Vol. 30,

pt. 2, p. 493.) Five different methods which can be used for annealing high speed steel attempt to disprove statements of Mr. Viall.

Furnaces for Tempering High-Speed Steel. By C. W. Scott. (In American Machinist, Vol. 30, pt. 1, p. 664-5.) Suggests furnaces most appropriate for small, and larger tool, and for all round work.

Hardening and Tempering High-Speed Steel. By J. Steele. (In American Machinist, Vol. 30, pt. 2, p. 543-4.) Practical discussion of treatment of high-speed steel tool, use of a forge, advice users not to temper high-speed steel, rehardening steel.

High-Speed Steel. Some Experiences in Annealing, Machining and Hardening, 1907. (In American Machinist, Vol. 30, pt. 1, p. 61.) Practical experience of man unfamiliar with methods of treating high speed steel.

On the Art of Cutting Metals. By F. W. Taylor. (In Transactions A. S. M. E., Vol. 28, p. 31, 279; disc p. 280-350, 24 inserts, reprinted in one volume by Amer. Soc. Mech. Eng. translated in Revue de Metallurgie Memoris, Vol. 4, p. 39-65, 108-84, 233-336, 401-66, abstr. In Engineering, Vol. 83, p. 54-5, abstr. In American Machinist, Vol. 30, pt. 42-6, 215-9, 247-51). P. 22-64. Modern high speed tools using high speed steel, chemical composition of tooi-steels for high-speed, discovery of high-speed, discovery of high-speed steel, American Machinist extracts those parts of practical shop value.

1908

The Manufacture of High-Speed Steel. By O. M. Becker. (In Cassier's Maga zine, Vol. 34, p. 291-9.) Charging of crucible, melting hole, heating and pour· ing of the melt, molding the ingot, annealing costs.

Possible Methods of Improving Modern High-Speed Turning Tools. By H. C. H Carpenter. (In Transactions Manchester Ass'n. Engrs. p. 1908-9, p. 81-110, disc pt. 111-2, 2 plates.) abstr. in Engineering, Vol. 206, p. 588-9. Composition manufacture, heat treatment of high-speed tools, manufacture of tool steel in electric furnace, welding high-speed to mild steel, summarizes possible improvements in manufacture and composition of high-speed steel.

Fabrication et Usage des Outils en Acier a Grande Vitesse. (In Revue Industrielle, p. 346-50, 361-3.) Manufacture and use of tools of high-speed steel. Discussion of paper by A. L. Valentine in the American Machinist includes composition of high-speed steels, analyses, tools used in tests, factors which influence the cutting speed, economic results, hardening high-speed steel, determination of the temperature uses of high-speed steel and economics which result from its use.

Hardening High-Speed Steels. By N. Gross. (In Iron Age, Vol. 81, p. 147; Mechanical Engineering Vol. 22, p. 5-7-8.) Rules to follow in heating and quenching high-speed steels, the necessity of proper hardening.

High-Speed Tool Hardening Furnaces. (In Mechanical Engineering, Vol. 21, p. 414-5, 830.) Illustrated description of Brayshaw's patent salt-bath for hardening and patent furnace for high-speed steel.

High-Speed Steel. By H. H. Hill. (In Mechanical Engineering, Vol. 22, p. 213-4; Mech. Wed., Vol. 44, p. 91-2; brief abstr. Iron Age, v. 81, p. 1406; abstr. Mechanical Engineering, Vol. 21, p. 334.) Paper read before the Liverpool Engineering Soc. Deals with the heat treatment or the annealing, hardening and tempering, grinding, finishing.

New High-Speed Steel Heating Furnace. (In Mechanical Engineering, Vol. 21, p. 382.) Brief illustrated description of high-speed steel tool heating furnace of the British Gas Furnace & Tool Co.

Tool Steel. By F. M. Osborn. (In Iron Age, Vol. 82, p. 1612-3) Abstract of pamphlet, a reprint of a paper before the Leeds Ass'n of Engrs. heat treatment after forging and grinding, results in turning tires at the New York Central shops, making of twist drills and milling cutters from high-speed steel.

A Plant for Hardening High-Speed Steels. (In Iron Age, Vol. 82, p. 1216-7.) Crucible gas furnace for the barium chloride bath, preheating furnace, an oil tempering furnace and quenching baths in the plant of Wheelock, Lovejoy & Co., New York.

La Durete a Chaud des Aciers. By Robin. (In Revue de Metallurgie Memoris, Vol. 15, p. 893-908. The hardness of steels when hot. P. 906-8. Study of high-speed steels, cooling curves.

Ueber Dreharbeit und Werkzeugstahle. By F. W. Taylor and A. Wallichs, translation. Berlin J. Springer Translation of "On the Art of Cutting Metals" reviewed in Zeitung des Ver. deut. Ing., Vol. 52, p. 970.)

Making and Using of High-Speed Steel Tools. By A. L. Valentine. (In American Machinist, Vol. 30, pt. 2, p. 6-9.) Composition of metal, forging, grinding and tempering of lathe tools and milling cutters.

The Treatment of High-Speed Steel. By E. Viall. (In American Machinist, Vol. 31, p. 314-6.) Treatment for Bohler's Styrian, Bohler's-Boreas, Jessop's Ark, Bethlehem self-hardening, Crescent self-hardening, Midvale special, Firth-Sterling Blue Chip, Allen's high-speed and Burgess' No. 5 special.

Annealing High-Speed Steel. By O. M. Becker. (In American Machinist, Vol. 32, p. 660-1, pt.1.) Furnace, quick and slow annealing, appliances for slow cooking, annealing temperatures, coolers left by annealing and electrical annealing.

1909

Annealing High-Speed Steel. By O. M. Becker. (In American Machinist, Vol. 32, p. 660-1.) Furnace, quick and slow annealing, appliances for slow cooling, annealing temperatures, colors left by annealing and electrical annealing.

English Versus American High Speed Steels. By E. T. Clarage. (In American Machinist, Vol. 32, pt. 1 p. 1031-2. Explanation of the hardening of carbon steels, of high-speed steels, and discussion of the progress made by American manufacturers over that of English.

Annealing High-Speed Steel. By W. G. Groocock. (In American Machinist, Vol. 32, pt. 2, p. 810.) Annealing by placing tool in a gas furnace at night raise it to 1400-1500 degrees, let it cool down in the furnace, and take it out about 10 o'clock the following morning, cool enough to handle, and soft enough to cut.

The Newer British High-Speed Steels. (In American Machinist, Vol. 32, pt. 1, p. 586-7.) Directions given by Samuel Osborn & Co. Ltd., for hardening lathe and planer to tools, data as to endurance under cut from tests of J. J. Saville & Co., Ltd., Thomas Nash & Sons, and Spear & Jacksons, Ltd.

A New Steel. (In Engineering, Vol. 86, p. 190; American Machinist, Vol. 32,

pt. 1, p. 337.) New high-speed steel which is hardened in water. Jonas and Culver of the Continental Steel Works experiments leading up to the discovery.

Some Tests of a New High-Speed Steel. (In American Machinist, Vol. 32, p 847-50, pt. 1.) Novo Superior steel in turning and drilling tests working on forged, rolled and cast steel and cast iron. Rules for forging, hardening and grinding.

1910

Development and Use of the New High-Speed Steel. By W. Carter. (In Engineering, Vol. 109, p. 154-5; Mechanical Engineering; Vol. 25, p. 191-3; abstr. in Stahl und Eisen, Vol. 30, p. 543; abstr. in Iron Trade Review, vol. 46, p. 480-3.) Paper before Birmingham Ass'n of Mach. Engrs. Development, composition heat treatment and use of new high-speed steels containing vanadium.

High-Speed Steel. By O. M. Becker. (In N. Y. McGraw-Hill Book Co. 360 pp.) The development, nature, treatment and use of high-speed steels. Problems involved in the use of high-speed tools, analyses of high-speed and special steels, reference table for determining cutting speeds.

High-Speed Tool Steel. By W. V. Brandt. (In Iron Age, Vol. 86, p. 1025; Mechanical Engineering, vol. 27, p. 38.) Method of manufacture and heat treatment.

A High-Speed Steel Tempering Furnace. (In Engineering, Vol. 107, p. 152.) Two-chamber gas furnace constructed by Churchill Machine Tool Co. of Manchester, England.

High-Speed Steel and Its Heat Treatment. By W. G. Smith. (In Mechanical Engineering, Vol. 26, p. 537-50.) Abstract of article in "The Armour Engr." history of high-speed steel, influence of carbon, chromium, tungsten, molybdenum, silicon, method of forging tempering, the barium chloride process and quenching.

Trempe des Outils en Acier Rapide. (In Revue Industrielle, p. 408.) Hardening of tools of high-speed steel. Refers to methods mentioned in American Machinist.

1911

Heat Treatment of High-Speed Tools. By C. P. Berg. (In Western Society Engineers Journal, Vol. 15, p. 738-64; Mechanical Engineering, Vol. 27, p. 154-8.) Relation between temperature and life of tools. Experiments to establish a guide as to how rapidly the steel should be heated under the high heat treatment by a heat absorption test, to determine at which degrees of temperature in the heat-treatment, the maximum cutting efficiency occurs for a steel of a certain chemical composition, to give the reasons for the relation found by these tests, and to illustrate the same by photo-micrographs.

The Practical Use of High-Speed Steel. By J. M. Gledhill. (In Mechanical Engineering, vol. 27, p. 762-6.) Composition, role of different metals, melting, annealing, forging, and hardening, grinding, uses of high-speed steels.

Trempe, Recuit, Cementation et Conditions d'Emploi des Aciers. By L. Grenet. Paris, Beranger 495 pp. Tempering, annealing, case-hardening. P. 348-451. Special steels, including high-speed; properties, forging, heat treatment.

Hardening and Tempering Steel. By B. E. Jones, Cassell & Co., New Y. 128 pp. P. 61-5. Heat-treatment of high-speed steel, p. 66-78 treatment of Mushet, "Novo" "Ultissimus", "Blue-chip" high-speed steels.

1912

Annealing High-Speed Steel. (In Machinery, Vol. 19, p. 257.) Packing in air-slaked lime, heated in an annealing oven to 1900 degrees to 50 degrees Fahr. for 9-10 hours, or packed directly in the oven, heat to 1700 degrees 50 degrees Fahr. for two hours.

Structure and Heat Treatment of Tool Steel. By J. V. Emmons. (In Mechanical Engineering, Vol. 29, p. 284-6; Iron Trade Review; Vol. 50, p. 450-2, one plate.) Gives heat treatment for both carbon or tool steel and high speed steel.

The Influence of Heat on Hardened Tool Steels. By E. G. Herbert. (In Journal Iron and Steel Inst., Vol 85, p. 358-78; Engineering, Vol. 93, p. 851-7; disc in Engineering, Vol. 113, p. 364-5; abstr. Iron Age, Vol. 89, p. 1465-8.) Refers especially to the heat generated in the cutting operation. Gives breaking tests, with resulting hardness, toughness and durability temperature curves for two high-speed steels.

Heating High-Speed Steel in a Blacksmith's Forge for Hardening. By F. A. Parsons. (In Machinery, Vol. 18, p. 884-5.) Covering of work with coating of fire clay and salt, and a thin shield of sheet metal, and then using coal forge fire for heating.

1913

Annealing High-Speed Steel. (In Machinery, Vol. 19, p. 431.) Methods given in Machinery, vol. 19, p. 275, disputed, and gives method with annealing chart used by one of the largest high-speed tool steel manufacturers in America.

Modern Tool Steels and High-Speed Tool Alloys. By G. S. Armstrong. (In Engineering Magazine, vol. 45, p. 833-42; v. 46, p. 63-76, 194-200, 400-15, 931-42.) P. 883-42. Theory of hardening, factors conducive to cutting speed, development of tool steels and alloys. P. 63-76, processes of manufacture mechanical treatment, machinery and equipment used, p. 194-200, application of carbon and alloy steels to specific uses. P. 400-15, heat-treatment, furnaces, baths and pyrometers, p. 931-42, machine tool operation at high cutting speeds, inserts.

Tool Steel From a Salesman's Point of View. By C. M. Bigger. (In Iron Age, vol. 91, p. 706-8; Mechanical Engineering, vol. 31, p. 380-2.) P. 707-8, high-speed steel composition and annealing and the influence of vanadium on the cutting speed and durability.

Structure des Aciers et Modifications Accompagnant les Traitments Thermique. By H. De Nolly. (In Bulletin Soc. l'Ind. Min. vol. 4, p. 371-82, 8 plates.) Structure of steels and modifications accompanying the heat treatment. Point of transformation, theory of hardening, use of microscope, dilation curves of a high speed steel, heated to 850 degrees 1050 degrees Cent.

1914

Aciers a Outils. By M. Denis. (In Revue de Metallurgie Memoirs, vol. 11, p. 4-94.) Tool steels. The cutting properties of tool steels following their heat treatment, and the practical utilization of these cutting properties.

Etude sur les Proprietes Generales des Aciers a Outils. By M. Denis. Revue de Metallurgie Memoirs vol. 11, p. 569-669; abstr. in Journal American Soc. Mech. Eng. vol. 36, p. 0164-6.) Investigation into the general properties of tool

steel, discussing the method of tests and heat treatment of various kinds of tool steels, detailed data of the tests, and conclusions from this data.

Note on the Transformation of Steels. By H. DeNolly and L. Veyret. (In Journal Iron and Steel Inst., vol. 90, p. 165-80; Engineering vol. 98, p. 631-2) Discussion of the carbide theory, the allotropic theory, and a theory of the dissociation of the carbide accompanied by the solid solution in the iron, of the carbon liberated by the association, proposed by the authors, and illustrated by curves of critical points of high speed tool steel.

Heat-Treatment of Steel. New York Industrial Press. 278 pp. P. 81-92. Heat treatment of high-speed steel including the Taylor-White process, annealing chart, and table giving kind of steel, method of cutting off unannealed bars, forging heat, directions for annealing, hardening heat, cooling medium, temper and grinding.

Influence du Temps de Chauffage Avant la Trempe sur les Resultats de cette Operations. By A. Portevin. (In Bulletin Soc. d'Encour, vol. 122, p. 206-82.) Influence of the time of reheating after the hardening on the results of this process.

1915

Modern Steels and Their Heat Treatment. By R. R. Abbott. (In Journal Frank-abstr. in Iron Age, vol. 95, p. 790-2.) Changes in structure of carbon and alloy steels, including tool steels by heat-treatment.

The Effect of Chromium and Tungsten Upon the Hardening and Tempering of High-Speed Tool Steel. By C. A. Edwards and H. Kikkawa. (In Journal Iron and Steel Inst., vol. 92, p. 6-30; disc p. 31-46, 3 plates, inset tables; abstr. Engineering, vol. 100, p. 349-52; disc p. 328-30; Engineering, vol. 120 disc p. 313-4, 344; Mechanical Engineering, vol. 36, p. 257-61, Jern-Kontorets Annaler Bihang, vol. 17, p. 103-14.) Influence of initial temperature and importance of secondary heat-treatment.

Manufacture and Uses of Alloy Steels. By H. D. Hibbard. (In U. S. Bureau of Mines Bulletin 100, 77 pp. Extract Mechanical Engineering, vol. 38, p. 4-6, 31-2.) P. 53-67. High-speed steels including manufacture, composition, effect of carbon, chromium, tungsten, molybdenum, cobalt, copper, sulphur and phosphorus in high speed steel, heat-treatment, theory patents and bibliography.

High-Speed Steels. By F. C. A. H. Lantsberry. (In Journal West of Scotland Iron and Steel Inst., vol. 22 p. 101-24; abstr. Iron Age, vol. 96, p. 238-41; Iron Trade Review, vol. 58, p. 487-91; Mechanical Engineering, vol. 36, p. 144-6.) Heat-treatment, theory of hardness, microstructure.

Points on Hardening High-Speed Screw Machine Tools. By R. A. Millholland. (In Iron Age, vol. 98, p. 745; Mechanical Engineering, vol. 36, p. 314.) Removal of decarbonized area to secure a good cutting edge.

1916

The Heat Treatment of Tool Steel. By H. Brearley. (In N. Y. Longmans Green & Co., 223 pp. Reviewed in Engineering, vol. 104, p. 401.) P. 181-210. High-speed steel includes melting difficulties, forging carbide, envelopes, milling cutters, clinking, flaking, cracking, annealing, red-hardness, high heat, quenching, lathe tests, over-heating, tempering, testing, blisters, grinding.

Initial Temperature and Critical Cooling Velocities of a Chromium Steel. By C. A. Edwards, J. N. Greenwood and H. K. Kikkawa. (In Journal Iron and Steel Inst. vol. 93, p. 114-40, disc p. 141-53, 2 plates, 4 inserts; abstr. Stahl und Eisen, vol. 36, p. 173-5; Engineering, vol. 101, disc. p. 465-7.) Shows by a discussion of a long series of experiments how sensitive one particular chromium steel is, to very slight variations in treatment.

German High-Speed Steel. (In Iron Age, vol. 98, p. 1111, quotations from Elektrotechnische Rundschau.) Composition of high-speed steel for lathe tools, brief outline of hardening process.

Hardening High-Speed Steel. (In Iron Trade Review, vol. 59, p. 270-1; also Mechanical Engineering, vol. 38, p. 165.) Directions distributed by the Vanadium-Alloys Steel Co., Pittsburgh.

The Transformations of Special Steels at High Temperatures. By K. Honda, K. Tawara and H. Takagi. (In Journal Iron and Steel Inst., vol. 93, p. 224-54, 3 plates.) Investigation on carbon steels, D. S. W. Steel, Ultra Capital Seebohm, New Capital Seebohm, Bohler Super-Rapid Novo, and Becher Diamond Steels.

The Metallography and Heat Treatment of Iron and Steel. By A. Sauveur. 2nd. ed. Sauveur & Boylston, Cambridge, Mass. 486 pp. P. 354-63. Chrome-tungsten or high-speed steel microphotographs, critical points, heating and cooling curves, etching.

Tool Steel Research. Transactions Manchester Ass'n Engineers, 1915-16, p. 421-5 disc p. 426-371. Abstract of interim report of the Tool Steel Research Committee of tests on ordinary high-speed steel.

1917

Heat-Treatment of High-Speed Steel Tools. By A. E. Bellis and T. W. Hardy. (In A. S. M. E. Bulletin 121, p. 61-8.) Iron Trade Review, vol. 60, p. 727-8; Am. Soc. Mech. Eng. Journal, vol. 39, p. 166-7; Iron Age, vol. 99, p. 425; Metallurgical and Chemical Engineering, vol. 16, p. 341-2; disc. A. I. M. E. Bulletin 123, p. 408-15, 124 p. 515-9; Iron Trade Review, vol. 60, p. 728-9; A. I. M. E. Bulletin 126, p. 998-1000. Discussion, table, plates of microphotographs of hardening experiments on five different high-speed tools.

Gas Furnaces, Their Design and Manipulation. By A. Forshaw. (In Engineering, vol. 104, p. 535-537, 589-91. P. 591, furnaces used in the hardening of high-speed steel, two chamber furnace, tool is placed in preheater and heated to redness, then transferred to hot chamber, heated to between 1200 degrees-1300 degrees Cent., then quenched in oil, or in "Feusalt" at a temperature of 230 degrees Cent.

Hardening High-Speed Steel Tools. By F. H. Koroff. (In American Machinist, vol. 46, p. 578.) Cyanide process for hardening steel tools with delicate edges.

Hardening High-Speed Steel. By J. Thompson. (In American Machinist, vol. 46, p. 344.) Instruction for hardening of high-speed steel cutters of tools of irregular shape and great accuracy.

1918

Pyrometry Applied to the Hardening of High-Speed Steel. By J. O. Arnold. (In Transactions Faraday Soc., vol. 13, p. 271-5.) Also Engineering, vol. 104, p. 527. Description of pyrometers in use at Sheffield University, where high-

speed steel is generally hardened from a temperature of 1300 degrees Cent., in a bath of barium chloride fused by the aid of iron electrodes.

Steel and Its Heat Treatment. By D. K. Bullens. 2nd. ed. N. Y. John Wiley & Sons, 483 pp. P. 332-48, chromium steels, p. 349-77, chromium-nickel steels, p. 378-86, vanadium steels, p. 387-402, manganese, silicon, tungsten and molybdenum steels. P. 403-10, high-speed steel including chemical composition, effect of tungsten, effect of chromium, critical ranges, Taylor-White method and American hardening practice.

The Hardening and Tempering of Steel. By C. A. Edwards. (In Transactions Manchester Ass'n of Engrs. 1917-19, p. 229-50, disc. 250-68, 1 plate; abstr. Engineering, vol. 125, p. 161-2; Engineering, vol. 105, p. 267-70.) Hardening and tempering of nickel, chromium, tungsten and high-speed chromium tungsten steels.

High-Speed Steel Hardening Furnace. (In Engineering, vol. 126, p. 319.) Brief description and illustration of furnace introduced by Brayshaw Furnaces Tools Ltd., Manchester.

Iron and Steel. By E. Oberg and F. D. Jones. (In N. Y. Industrial Press, 328 pp.) P. 276-97, High Speed Steel, includes origin, Taylor-White process of heat-treatment, production of high-speed steel, effect of different elements of high-speed steels, hardening practice, tempering, annealing, uses.

How to Treat High-Speed Steel. By J. L. Thorne. (In Iron Age, vol. 102, p. 314.) Abstract of paper on the metallurgical treatment of high-speed steel before the Steel Treating Research Society of Detroit.

Recherches sur l'Acier a Coupe Rapide Faites au Laboratoire du Harvard. By M. Yatesevitch; translated by H. Herbert. (In Revue de Metallurgie Memoirs, vol. 15, p. 55-109, bibliography 109-115.) Research on high-speed steel made at the Laboratory of Harvard. Study on the "Dreadnought" steel of the Halcomb Steel Co. on determination of the modifications in structure and caused by heating and cooling under various conditions, microscopic study of heat-treatment, relation between hardness and heat-treatment.

A Special Tool Steel Heating Furnace. (In Iron Age, vol. 101, p. 553.) Furnace for use with tool of high-speed steel, patented by W. R. Bennett, of the Bennett Metal Treating Co., Elmwood, Conn.

1919

The Hardening of Steel. By H. C. H. Carpenter. (In Engineering, vol. 107, p. 340-1, 386-90.) Paper at the Royal Institution. Theoretical paper attributing hardening to the existence of a hard amorphous constituent in the steels. Refers in the discussion to martensite and to high-speed tool steels.

Manufacture and Use of Alloy Steels. By H. D. Hibbard. J. Wiley & Sons, N. Y. 96 pp. P. 68-87, manufacture, composition, heat-treatment, theory, testing, using and patents of high speed steels. Bibliography.

Heat-Treatment of Chisel Steel. By N. B. Hoffman. (In Journal American Steel Treaters Society, vol. 2, p. 155-60.) Historical review, heat treatment of high-speed for chisel, tests.

The Properties of High-Speed Steel. By G. J. Horvitz. (In Journal American Steel Treater's Society, vol. 1, p. 324-48; abstr. Iron Age, vol. 103, p. 1711-4.) Composition, crucible and electric processes of manufacture, hardening heat treatment, theory of hardening, physical properties, 13 microphotographs.

A Brief Record of Results of the Annealing of a Chromium Molybdenum and a Chromium Steel. By J. O. Liebig. (In Journal Am. Soc. Steel Treaters, vol. 2, p. 168-71.) Results and microphotographs.

American Practice for Hardening High-Speed Steel. By A. F. McFarland. (In Proceedings Steel Treating Research Society, vol. 2, no. 6, p. 34-6, disc. p. 36, 38, 40, 42, 45-6.) Practice of Bullens, Brearly, Taylor-White, prevention of scale, relation of cutting efficiency to hardness, file tests.

Engineering Machine Tools and Processes. By A. G. Robson. Longmans, Green & Co., N. Y., 307 pp. P. 51-8. Treatment of tool steels and tools including high-speed tool steel treatment, brief discussion of alloys used in high-speed steel, melting of charge, annealing, forging and hardening, grinding, results of use of A. W. high-speed steel.

Heat Treatment of High-Speed Steel. By C. U. Scott. In Journal American Steel Treaters Society, vol. 1, p. 299-301. Practical instructions concerning hardening of high-speed steel.

Electric Welding of High-Speed Steel and Stellite in Tool Manufacture. By P. T. Van Bibber. (In American Machinist, vol. 50, p. 425-32.) Shows a practical way to save an enormous amount of high speed or other steel that is wasted annually. It shows how new tools may be produced so as to use the high-priced steel only for the vital parts.

1920

Some General Principle of Tool Hardening. By A. E. Bellis. (In Journal American Steel Treater's Society, vol. 2, p. 364-6.) Application of the principle of uniformity to the hardening of high speed steel tools.

On the Structural Constitution of High-Speed Steel Containing Chromium and Tungsten and the Effect of These Elements on its Hardening and Tempering. By K. Honda and T. Murakami. (In Science Report of the Tokoku Imperial University, vol. 9, p. 143-68, 7 plates; Journal Iron and Steel Inst. Reprint 15.) Object of research is to ascertain the structural constitution of high-speed steel, the change of these constituents during heating and cooling, and the effect of these constituents upon hardening and tempering.

A Comparative Test Upon High-Speed Steels. By A. J. Langhammer. (In Chemical and Metallurgical Engr., vol. 22, p. 829-32, p. 889-92, 939-42; American Machinist, vol. 52, p. 979-82.) P. 829. Current sales practices, general review of tool steel, high-speed steel, stellite, influence of chemical composition, inconsistency of recommended heat-treatments, table of maker's recommendations for treating lathe and planer tools, p. 889. Conditions entering into the testing of a tool for cutting as listed by Taylor—are discussed, method of eliminating most of the variables from a comparative test for the efficiency of several brands of commercial tool steel. P. 939. Detailed description of tests on 16 high-speed steels, with data as to performance, chemical composition, heat-treatment and hardness.

Hardening of High-Speed Steel. By A. H. d'Arcambal. (In Railway Mechanical Eng., vol. 94, p. 665-6.) Describes experiments made to determine the effect of various hardening methods on the hardness microstructure and cutting efficiency of high-speed steel.

Temperature Ranges in Hardening Steel. By C. T. Hewitt. (In Iron Age, vol.

106, p. 67-8.) Gives a comparison of scleroscopic results and hardening temperatures, the effect of overheating and enlargement of the grain.

1921

Various Methods for Hardening High-Speed Steel. By A. H. d'Arcambal. (In Chemical and Metallurgical Engineering, vol. 25, p. 1150-1; also in American Machinist, vol. 56, p. 212-3.) Gives advantages and disadvantages of different methods of hardening high-speed steel that have been proposed in 20 years.

Heating and Quenching High-Speed Steel. By A. E. Bellis. (In Transactions American Society for Steel Treating, Vol. 1, p. 441-45.) Gives reasons and advantages for processes used in heating and quenching high-speed steel

Prevention of Hardening Cracks and the Effect of Controlling Recalescence in a Tool Steel (By. S. N. Brayshaw. (In Journal Iron & Steel and Inst., Vol. 103, p. 131-216, discussion p. 217-49, abstr. in Iron Age, Vol. 107, p. 1400-1.) Describes tests to determine cause of cracks, and methods of prevention.

Heat Treatment of Rock-Drill Steel. By G. H. Gilman. Abstracts 1921. (In Mining and Metallurgy, Vol. 174, p. 35, p. 38-9, Eng. and Contr., Vol. 56, p. 55-6.) Gives practical hints on ways of prolonging the life of rock drill steel and getting better results.

Action of Internal Stress on Tool Steel.. By C. N. Greenwood. (In Forging and Heat Treating, Vol. 7, p. 560-63.)

Hardening of Tungsten Steels. (In Engineering, Vol. 112, p. 517.)

Heat Treating of Tool Steels. By L. A. Lanning. (In Blast Furnace and Steel Plant, Vol. 9, p. 706-7.) Effect of rates of heating, temperatures, and quenching medium upon the dimensions of cylindrical pieces of tool steels.

Note on Double Preheating High-Speed Tools for Hardening. By A. E. MacFarland. 1921. (In Transaction American Society Steel Treating, Vol. 1, p. 306-9.) Discusses decarbonization and the advantages of double preheating.

Theory and Practice in the Drill Sharpening Shop. By J. A. Noyes and V. M. Lee. (In Engineer and Contractor, Vol. 55, p. 387-9.) Gives 15 rules for good practice in treatment of drills.

Oxidation of Carbon Tool Steel on Heating in Air. By H. Scott. (In Chemical and Metallurgical Engineering, Vol. 25, p. 72-4.) Describes experiments made to determine to what extent decarbonization and scaling are likely to alter the structure and dimensions of carbon tool steel under heat treatment.

Relation of High Temperature Treatment of High-Speed Steel to Secondary Hardening and Red Hardness. By H. Scott. (In Transactions American Society for Steel Treating, Vol. 1, p. 511-26. Reprinted from U. S. Bur. Stds., Sci. Paper 395.) An investigation to determine the alloy forms in heat treated high speed steel, and the behavior of the physical properties of the steel.

Heat Treatment of High-Speed Steel. By J. Thorne. (In Transactions American Society for Steel Treating, Vol. 1, p. 727-33.) Takes up the influence of elements on high-speed steel, and the method of heat treating.

Proper Heat Treatment for High-Speed Steel.. By J. L. Thorne. (In Canadian Machinist, Vol. 26, p. 36-7, 53.)

USES AND TESTS OF HIGH-SPEED STEEL

1900

Improvements in Tool Steel. (In Mechanical Engineering, Vol. 6, p. 319-20.) Account of tests by the Bethlehem Steel Co. to show the representatives of the American Technical Journals the behavior of tools made by the new process.

Ueber den Taylor-Whiteschen Werkzeugstahl. By Reuleaux. (Sitz. des Vereins zur Beförderung des Gewerbfleisses, Nov. 5, p. 179-89, abstr. in Glückauf, Vol. 37, p. 236-7.) Taylor-White tool steel as shown at Paris exhibition.

The Taylor-White Process of Treatment of Steel. (In American Machinist, Vol. 23, p. 183-4.) Tests of properties of lathe tools made of steel treated by the Taylor-White process and Mushet steel.

Werkzeugstahl der Bethlehem Steel Co. In Zeitung des Ver. deut. Ing., Vol. 46, p. 1666.) Discussion in the "Rundschau" of the cutting speeds and composition of the new steel of the Bethlehem Steel Co.

1901

Acier pour Outils. (Bulletin Society d' Encouragement Ind., p. 539-42.) Steel for tools. Discussion of report of commission of the Association of German engineers.

The Taylor-White Process of Treating Tool Steel, and Its Influences on the Mechanic Arts. By C. Day (In Journal Franklin Institute, Vol. 152, p. 161-78; abstr. Engineering, Vol. 72, p. 416; Mechanical Engineering, Vol. 8, p. 574-5; Iron Age, Vol. 68, Sept. 19, p. 10-13. Outline of the Taylor-White process, application at the Link-Belt Engng. Co.'s works.

Versuche mit einem neuen Werkzeugstahl. By E. Heissig. (In Stahl und Eisen, Vol. 21, p. 26.) Experiments with a new tool steel at the works of Böhler & Co. at Wient, Berlin.

Schnelldrehstahl. (In Zeitung des Ver. deut. Ing., Vol. 45, p. 1377-86.) High speed steel, Report of the committee of German Engrs. of the Berlin District O. Lasche, chairman for Feb. 15-July 12, about 250 different steels. Preparation of steels, testing, time curves for blunting the tools, tables giving cutting speeds, and feeds, recording of the tests.

Special Tool Steel. (In Mechanical Engineering, Vol. 8, p. 379-80.) Test of Taylor-White tool steel as compared with Mushet steel. Tests on Speedicut steel of Thos. Firth & Sons, Ltd., Sheffield.

Der Stahl der Bethlehem Steel Co. und der Taylor-White Process. By O. Thallner. (In Stahl und Eisen, Vol. 21, p. 169-76, 215-20.) The steel of the Bethlehem Steel Co. and the Taylor-White process. Report of personal investigation of the new process undertaken in the interests of "Bismarckhutte" who intended to acquire the rights for Germany, but as a consequence of the report, desisted.

Das Wesen des Amerikanischen Schnelldrehstahles und des Taylor-White-Verfahrens und Uber die Ergebnisse mit Deutchen Schnelldrehstahlen. By O. Thallner. (In Zeitung Des Ver. deut. Ing., Vol. 45, p. 1609-10.) The American high-speed steels, the Taylor-White process and the results with German high-speed steel.

Tool Steel. (In Engineering, Vol. 72, p. 145.) Mention of new steels made by See-

bohm and Diechstahl and tested at works of Sir W. G. Armstrong & Co., to compete with the new American high-speed self-hardening steel.

1902

Acier pour outils. (In Revue Industrielle, 1902, p. 249-50.) Outline of tests and results of the Association of German Engrs. to get the best results with high-speed steel, following the Taylor-White process.

Einige Betrachtungen Uber Schnelldrehstahle. (In Zeitung f. Klein u Strassenhahnwesen. Dec. 16, 1902.) Notes on high-speed steel. Tabulated resuits of tests of the Bischoff steel at cutting speeds of 16-64 meters per min.

An Improved High-Speed Tool Steel. (In Mechanical Engineering, Vol. 10, p. 773.) Paragraph concerning steel produced by a new process at the Bismark Furnace in Silesia, Germany. Comparative figures of Taylor-White steel and carbon tool steel.

New Tool Steels. By J. W. E. Littledale. (In Transactions Northeast Coast Institution of Engrs. and Shipbuilders, Vol. 18, p. 21-37.) Tests on new rapid steels.

Schnelldrehstahle und deren Anwendung. By O. Mulacek. (In Stahl und Eisen, Vol. 22, p. 454-6, 528-30.) High-speed steel and its use, composition, theory of the hardening of the steel use in cutting, machine, speeds and tests. Paper read before the Mittelthuringer Bezirkverein deutscher Ingenieure.

A New High-Speed Tool Steel. (In Engineering, Vol. 74, p. 190.) Description and tests of Air Novo steel, made by Jonas and Culver of the Continental Steel Works, Sheffield.

The Novo Air Steel. (In Iron Age, Vol. 69, p. 9, May 1.) Tests of a high-speed steel, air hardening or hot water hardening, of Jonas & Culver, Ltd., Sheffield, England.

New Tool Steels and Their Advantages. (In Iron and Coal Trades Review, Vol. 64, p. 1516-8.) Results of tests of new high-speed steels made by Jessop & Sons, Jonas & Culver, the Berlin Section of the Society of German Engrs., Schoeller & Co., followed by outline of Taylor-White process, that data on saving by use of high-speed tools, and data on pressure and feeds to be used.

Nouvel Acier dur pour Outils a Grand Travail. (In Revue Industrielle, p. 348-9.) New hard steel for high-speed tools. Description, table and graph showing power and speed obtained by new "Belmont et Moine" steel marked "Ideal."

1903

American Tests of Rapid Cutting Tool Steels. (In Iron Age, Vol. 72, p. 16-19, Dec. 31.) Tests on high-speed steel by Lodge & Chipley in their shoproom.

"A. W." Rapid Cutting Tool Steel. (In Engineering, Vol. 76, p. 759, Illus. P. 756.) Details of machines used by Mr. Gledhill to test the new high-speed steels.

Schnelldrehbank und Schnelldrehstahl. By F. Bischoff. (In Stahl und Eisen, Vol. 23, p. 132-4.) High-speed lathe and high-speed steel. Use of Bischoff steel in turning other steels.

The Requirements of Machine Tool Operation with Special Reference to the Motor Drive. By C. Day. (In Iron Age, Vol. 71, Jan. 8, p. 16-21; American Machinist Vol. 26, p. 370-2, 404-7, 441-2.) P. 17-18. Tests with steel made by the Taylor-White process of self-hardening. Paper before New York Electrical Society.

High-Speed Tool Steel. (In Mechanical Engineering, Vol. 12, p. 579-80.) Editorial on report of J. T. Nicholson to the Manchester Association of Engrs.

High-Speed Tool Steel. (In Engineering, Vol. 75, p. 81-2.) Particulars of tests made for the purpose of comparing the efficiency of ordinary twist drills with that of twist drills made of high-speed steel at works of Yarrow & Co., Poplar, England.

High-Speed Tool Steel. (In Engineering, Vol. 95, p. 119.) Editorial concerning advantages of use of new steels.

The New Tool Steel and Its Effect on Machine Methods. By C. T. King. (In Wisconsin Engineering, Vol. 7, p. 255-61.) Development of tool steel, discovery or high-speed steel, cause of change in steel structure by heat-treatment.

Schnelldrehstahle. By E. Körting. (In Zeitung des Ver. Deut. Ing., Vol. 47, p. 287.) Brief discussion of experiments on high-speed steel by the Körting firm.

Comparative Trials of High-Speed Steels. By G. Kuwaoi. (In American Machinist, Vol. 26, p. 1230-1) Report of tests of Noro, Speedicut, High-Speed Alpha, and Capital steels.

High-Speed Tool Steel. By W. Lodge. (In Iron Trade Review, Vol. 36, p. 52, May 21.) Advantages to out-put by use of high-speed steel.

High-Speed Cutting Steel. By J. Miley. (In Iron and Coal Trade Review, Vol. 66, p. 299-300; abstr. in Mechanical Engineering, Vol. 11, p. 197-8.) Progress made in the manufacture of high-speed tool steel in the Sheffield district, and the results of its use in English workshops.

Report on Experiments with Rapid-Cutting Steel Tools made at the Manchester Municipal School of Technology under the auspices of a Joint Committee of Members of the Manchester Ass'n. of Engrs. and of Members of the School of Technology Sub-committee, together with Prof. J. T. Nicholson. By J. T. Nicholson. (In Manchester p. 590-5, 636-46, Engineering, Vol. 96, p. 416-7, 419, 473-4, American Machinist, Vol. 26, p. 1620-2, 1658-62, Mechanical Engineering, Vol. 12, p. 586-91, 630-9, 656-61. abstr. in Iron Age, Vol. 72, p. 28-9. Nov. 26.) Arrangements for the experiments, information supplied to the committee by the tool-makers, lathes and other apparatus. Results of tests. 25 tables.

The Inefficiency of the Standard Lathe for High-Speed Cutting. The Maximum Duty of High-Speed Steel. By H. M. Norris. (In American Machinist, Vol. 26, p. 838-40.) Tests of standard lathe with Novo steel.

Rapid-Cutting of Metal—Why Don't It Get Hot? By W. Osborne. (In American Machinist, Vol. 26, p. 531.) Letter asking why high-speed steel does not generate the heat that would be expected from the rate at which it is run.

Rapid Tool Steels. (In Engineering, Vol. 76, p. 255-6; Iron Age, Vol. 72, Sept. 17, p. 42-3.) Discussion of various tests resulting from the exhibition by the Bethlehem Steel Co. of the working capacity of the Taylor-White tools at the Paris Exhibition of 1900; the Berlin Trials, and the theories of Reiser and Spuller.

Notes on High-Speed Tool Steels. By H. H. Suplee. (Inst. Mech. Engrs. Proceedings, pt. 3-4, p. 457-69, disc. 467-81, Engineering, Vol. 476, p. 146-7, abstr. Engineering, Vol. 95, p. 112-3, Mechanical Engineering, Vol. 121, p. 295.) Verified data as to the use of high-speed tool steels in the works of the Union Pacific Railroad at Omaha, Neb.

Tests With High-Speed Tool Steels. (In Mechanical Engineering, Vol. 12, p. 357-8.) Tests of cutting speeds with high speed tool steels on medium steel, wrought iron, and cast iron, by H. H. Vaughan at the Collinwood shops of the Lake Shore & Michigan Southern Railway.

1904

High-Speed Steel Twist Drills and Milling Cutters. By Camell, Laird & Co. (In Engineering, Vol. 98, p. 110.) Letter reporting tests on "0172" high-speed steel, which show great economy in its use, notwithstanding the extra cost.

High-Speed Tool Steel Economies. By Cammell, Laird & Co. (In Iron Age, Vol. 74, p. 21, Aug. 25.) Statement of the costs of drilling with ordinary steel drill, and with a high-speed steel drill.

Machine Tools and High-Speed Steel. By J. A. Carney. (In Iron Age, Vol. 73, p. 16, Jan. 7.) Advantages of reconstructing machine tools to use high-speed steel.

Experiments with Rapid-Cutting Tools. By C. Day. (In Transactions Inst. Engrs. and Shipbuilders in Scotland, Vol. 47, p. 170-8, disc. 178-91, abstr. Engineering, Vol. 47, p. 230-232.) Paper based on report of tests made by the Manchester Association of Engrs. and the Manchester City Council.

Considerations sur le Choix D'un Acier a Outils a Grand Rendement. By M. L. Demozay. (In Revue de Metallurgie Memoirs, p. 361-89, 419-57.) Considerations on the choice of a tool steel. Mathematical paper referring to high-speed tool steel tests at Manchester.

Beitrag zur Kenntnis und Theorie des Schnelldrehstahls. By H. Eckardt. (In Stahl und Eisen, Vol. 24, p. 611-3, extract in American Machinist, Vol. 27, p. 1080-1.) Contribution to the knowledge and theory of high-speed steels. Discussion of the properties of the Taylor-White and European steels made after the Taylor-White process. Deals especially with the cutting and high-speed qualities.

The Introduction of High-Speed Steels in Engineering Work Shops. By F. Fielden. (In Engineering, Vol. 77, p. 318-9.) Brief discussion of hardening and grinding of new steels, objections to introduction into work shop, charts and data needed by operators.

The Development and Use of High-Speed Steel. By J. M. Gledhill. (In Journal Iron and Steel Inst., pt. 2, p. 127-67, disc. p. 168-82, Engr. vol. 98, p. 482-3, disc. Engineering, Vol. 78, p. 675, American Machinist, Vol. 27, p. 1696-1700, 1730-4, Vol. 28, p. 46-51, Mechanical Engineering, Vol. 1, p. 734-6, 782-5, 851-3, 890-2, abstr. in Iron Age, Vol. 76, Nov. 10, p. 12-15, in Iron Trade Review, Vol. 37, p. 83-9, Nov. 3.) History, composition, effect of combination of iron and carbide with tungsten and chromium, with tungsten, with molybdenum and chromium, molybdenum and tungsten and chromium; influence of each; analyses; heat-treatment, results of tests. 7 plates.

High-Speed Tool Steel—Its Manufacture and Use. By J. M. Gledhill. (In Engineering, Vol. 97, p. 266-7, Mechanical Engineering, Vol. 13, p. 396-8, 444-6, Iron and Coal Trades Review, Vol. 63, p. 1197-1201, American Machinist, Vol. 27, p. 352-807, abstr. in Iron Trade Review, Vol. 37, p. 44-7, April 21.) Paper read before the Coventry Engineering Society, March 4, 1904. Manufacture of crucible steel, process of converting crucible steel into high-speed steel, annealing, forging and hardening the tools, heat treatment of high speed steel. Cutting tests.

On the Practical Application of the Results of the Manchester Experiments with

Rapid Cutting Tool Steels. By C. F. Hatton. (Published by the author, London, 31 pp.) Abstr. in American Machinist, Vol. 27, p. 538-9.

High-Speed Steel Tests at St. Louis. (In Iron Trade Review, Vol. 37, p. 53, Oct. 20.) Conditions of Test. Results given on p. 62.

High-Speed Steel and the Manufacture of Armor-Piercing Projectiles. (In American Machinist, Vol. 27, p. 877-80.) Use of "Blue Chip" high-speed steel at the Demmler plant of the Firth-Sterling Steel Co. of Pittsburgh, Pa.

High-Speed Steel for Milling Cutters. (In American Machinist, Vol. 27, p. 1149-50. Use of milling cutters of Novo steel by the Cincinnati Milling Machine Co.

High-Speed Tool Steel. (In Engineering, Vol. 78, p. 349.) Tabulated results of tests on twist-drills and milling cutters manufactured from "0172" high-speed tool steel by Cammel, Laird & Co.

Les Aciers Rapides a Outils. By H. Le Chatelier. (In Revue de Metallurgie, Memoirs, 1904, p. 334-47.) Rapid steel for tools, composition, analyses and tests of high-speed steels resulting from exhibition of steels made by Taylor-White process in Paris, 1900.

High-Speed Tool Steel Tests. By Lodge and Shipley Machine Tool Co. (In American Machinist, Vol. 27, p. 10-14.) Report of a series of experiments to determine the relative value of the several high-speed steels, the speed limit it is possible to maintain, and to fix the relative breaking-down point of each grade of steel tested.

Manchester High-Speed Steel Tests. (In Engineering, Vol. 97, p. 142.) Discussion of the reply to Dr. Nicolson on the main points brought forward during the discussion of his report on the series of high-speed steel tests carried out under his supervision at the Manchester School of Technology.

Alloy Steel. By W. Metcalf. (In Proceedings Amer. Soc. Test. Mat., Vol. 4, p. 204-10, disc. p. 211-4, American Machinist, Vol. 27, p. 961-2.) Development and value of high-speed steel. Analyses of two brands.

High-Speed Turning. By J. Miley. (In Engineering, Vol. 97, p. 146.) Abstract of paper before Leeds Ass'n. of Engrs. on progress of British manufacture of high speed steel, and on experiments to show the efficiency of the steel.

Notes on Tests of Rapid-Cutting Steel Tools. By C. Pendlebury. (In Engineering, Vol 97, p. 331-2. Results of tests on speed of cutting, amount of metal removed, power required to remove the metal with special reference to the Manchester trials of the Manchester Association of Engrs.

Profit in the Use of High-Speed Steel Tools. (In Iron Age, Dec. 1, p. 14-5.) Discussion of costs and savings, change in piece rate, etc., caused by the introduction of new steel tools.

Notes on "High-Speed Steel," etc. By J. Vose. (In American Machinist, Vol. 27, p. 586, 588. Use of high-speed steel, lubrication, finishing, change in lathe design.

High-Speed Steel for Finishing. By P. Wesley. (In American Machinist, Vol. 27, p. 529-30.) Results of experiments on use of high-speed steel tool for finishing. Tool was heated till the point burnt off, and cooled in the air blast.

1905

High-Speed Steel in the Factory. By O. M. Becker and W. Brown. (In Engineer-

ing Magazine, Vol. 29, p. 913-20, Vol. 30, p. 88-98, 241-51, 388-413, Vol. 31, p. 231-46, 397-405, 712-21.) P. 913-20. Advantage of high-speed steel over the older tool steels; p. 88-98, details of introducing machines using high-speed steel in place of those using carbon steels; p. 241-51, making of tools from high-speed steels; 6. 388-413, operation of the tools and of the machines carrying them; p. 234-46, adoptability of alloy steel tools; p. 397-405, the tool at work; p. 712-21, feeds and speeds for the new tool steels.

High-Speed Tool Steels. By L. P. Breckenridge. (In Univ. of Illinois Circular No. 1, of the Engineering Experiment Station. 9 pages.) Properties of tool steels, advantages of high-speed steels. Results of experiments made by Manchester School of Technology, England. By Bohler Bros. & Co. Vienna and Berlin, Union Pacific Railroad Shops, Berlin Section Vereines Deutscher Ingeniere, Bethlehem Steel Co. and Armstrong, Whitworth & Co.

Tests of High-Speed Tool Steels on Cast Iron. By L. P. Breckenridge and H. B Dirks. University of Illinois Engineering Experiment Station Bulletin No. 2. Abstr. in Mechanical Engineering, Vol. 17, p. 376-7.

Comparative Tests of Common and High-Speed Drills. (In American Machinist, Vol. 28, p. 218-20.) Results of drilling tests at the Works of the Rand Drill Co.

Les Aciers a Outils a Coupe Rapide. Preparation et Emploi dans les Ateliers. By J. Garnier. (In Genie Civil, Vol. 47, p. 105-8.) Tool steels for high-speed. Preparation and use in the shops. Composition, influence of the various constituents, preparation and treatment of rapid steels, applications, results of use of "A.W," steel.

The Practical Use and Economy of High-Speed Steel. By J. M. Gledhill. (In Iron and Coal Trades Review, Vol. 71, p. 1690-92; Engineering, Vol. 80, p. 979-801; Iron Trade Review, Vol. 38, Dec. 7, p. 22-8; abstr. American Machinist, Vol. 29, p. 270-2, Mechanical Engineering, Vol. 16, p. 779-81.) Abstr. of paper read before the Gladgow and West of Scotland Foremen Engr. of Ironworkers Ass'n. Actual practice with high-speed steel for cutting.

Aciers a Outils a Coupe Rapide. By L. Guillet. (In Revue Industrielle, Vol. 1905, p. 315-6, 323-4, 338-9, 358-9; Memoirs Soc. Civ. de France, pt. 1, p. 919-45.) P. 315. Definition. History, transformation points of carbon steels; p. 323, theory of the hardening of carbon steels. To harden a carbon tool steel, it is necessary that the hardening temperature be higher, than transformation point A'; p. 338, composition of high-speed steel, constitution of chromium and of tungsten steel; p. 358-9, transformation points of chrome tungsten steel of an influence of the constituents; p. 368, properties, treatment, results obtained at Manchester and at Birmingham.

Sind de Schnelldrehspane ebenso Aufgebaut wie die mit den Alten Messern Genommenen? By M. Kurrein. (In Oesterr. Wochenschr f. d. Oeffent Baudienst, Sept. 16, 1905.) Is the constitution of chips from high speed steel the same as from the older cutting steels?

High-Speed Steels. By W. Lodge. (In Iron Age, Vol. 73, p. 697, April 7; Iron Trade Review, Vol. 27, p. 101-3, April 7.) Changes in machine tool design caused by acceleration of pace.

High-Speed Tool Steel and the Lathes for Its Use. By T. J. Nicholson. (In Engineering, Vol. 99, p. 169.) Brief abstract of paper read before the Leeds Univ. Eng'ng. Soc. paper mostly with the force exercised during the operation of cutting.

Tests of High-Speed Tool Steels. (In American Machinist, Vol. 15, p. 49.) Report of tests at the St. Louis Exhibition, but three steels competing.

Tests of Tools of High-Speed Steel. (In Engineering, Vol. 99, p. 200.) Abstract of report of the Committee of Judges at the International Exhibition at St. Louis on tests on high-speed steel. Tabulated results of tests on McInnis, Allen, and Victoria steels.

The Uses of High-Speed Steel. (In Machinery, Vol. 11, p. 420-1.) Questions arising on the introduction of high-speed steel into the shop.

1906

Les Aciers Rapide. (In Revue Industrielle, p. 177.) Rapid steels, refers to tests of Withworth at the exposition of Liege on A. W. steel, and the examples mentioned by Gledhill in the Amer. Machinist.

Tempering and Cutting Tests of High-Speed Steels. By H. C. H. Carpenter. (In Journal Iron & Steel Institute, 1906, pt. 3, p. 377-96, 5 plates abstr. in Engineering, Vol. 82, p. 300-4, Stahl und Eisen, Vol. 26, p. 1018-9, transl. in Metallurgie, Vol. 3, p. 511-22, abstr. Mechanical Engineering, Vol. 18, p. 164-70.) Report of research to ascertain whether the temperature at which high-speed steels soften can be pushed higher than 700 degrees Cent.

High-Speed Steel. By E. Childe, and W. T. Sears. (In American Machinist, Vol. 29, p. 67-8.) Abstr. of papers before the Boston Branch of the National Metal Trades Ass'n. on use of high-speed steel, costs, and records of milling cutters.

L'emploi Pratique des Outils an Acier Rapide. (In Revue Industrielle, p. 387.) Editorial on the practical uses of tools of high-speed steel, referring to series in Engineering Magazine by Becker.

High-Speed Tool Steel Tests. (In Engineering, Vol. 82, p. 67-8.) Discussion of tests on eight brands of high-speed steel by Prof. L. P. Brenckenridge and Mr. H. B. Dirks of the University of Illinois.

1907

Notes on the Manufacture and Upkeep of Milling Cutters. By H. T. Ashton. (In Inst. Mech. Engrs. pt. 3-4, p. 1021-9; ast. in Mechanical Engineering, Vol. 20, p. 903-6; disc. p. 1030-66 plates 83-6; Iron Age, Vol. 81, p. 953; Engineering, Vol. 84, p. 870-4.) Discussion of difficulties of extending the use of high-speed steel to milling cutters of complicated shape, required when cutting to give an accurate finish and a good surface.

A Comparison of the Production Values of High-Speed Tool Steels and Carbon Steels. By G. Bilhab. (In American Machinist, Vol. 30, pt. 2, p. 893-5.) Considers the introduction of the use of high-speed steel tools into the shop, the use in combination with high powered machine tools, costs and savings.

An Analysis of the Evolution of Modern Tool Steel. By H. C. H. Carpenter. (In Engineering, Vol. 83, p. 569-71, 633-4.) Current theories of hardening the wear of tools in cutting metals, epochs in the history of tool-steels, possible future developments. Refers especially to F. W. Taylor's work on the "Art of Cutting Metals."

High-Speed Tool Steel. By H. C. H. Carpenter. (In Iron Age, Vol. 79, p. 822-4.) Contribution to the discussion of F. W. Taylor's "On the Art of Cutting Metals" and reprinted from the proceedings of the A. S. M. E. Includes cor-

rections red hardness, structure of steel, the heat at which tools cut best, other hardening agents than carbon, the action of chromium and tungsten, classification of types cutting tools, and the question of maximum temperature.

Actual Results with High-Speed Steel. By F. H. Colvin.(In American Machinist, Vol. 30, pt. 2, p. 708-9.) Information obtained from shops using steel in various ways, including annealing, speeds on low-carbon steels, handling of high-speed steels, and the question of saving by the use of high speed steel.

Aciers Chrome-Tungsten. By L. Guillet. (In Revue de Metallurgie Memories, Vol. 4, p. 5-24.) Chrome-tungsten steels. p. 1920. Use of chrome-tungsten steel as steel for high-speed cutting.

Machine-Tool Design as Affected by the Use of High-Speed Cutting Tools. By J. T. Nicholson. (Engineering, Vol. 83, p. 870-1.) Changes in design of the lathe.

High-Speed Steel Tools. By E. R. Norris. (In Electrical Journal, Vol. 4, p. 246-58.) The making of the tool, the life of the tool, shape of the tool, application of high speed tools. Refers to F. W. Taylor's "On the Art of Cutting Metals."

Service List of High-Speed Tool Steels. (In Mechanical Engineering, Vol. 20, p. 445-7.) Method of keeping records; tabulated results.

On the Art of Cutting Metals. By F. W. Taylor. (In Transactions A. S. M. E., Vol. 28, p. 31-279; disc. p. 280-350, 24 inserts, reprinted in one volume by Amer. Soc. Mech. Eng. translated in Revue de Metallurgie Memoirs, Vol. 4, p. 39-65, 108-84, 233-336, 401-66. Abstr. in Engineering Vol. 83, p. 54-5, abstr. in American Machinist, Vol. 30, pt. 42-6, 215-9, 247-51.) P. 222-64. Modern high-speed tools using high-speed steel, chemical composition of tool steels for high-speed, discovery of high-speed steel, Amer. Mach. extracts those parts of practical shop value.

Taylor's Untersuchungen Uber Rationelle Dreharbeit. By A. Wallichs, A. and O. Peterson. (In Stahl und Eisen, Vol. 27, p. 1053-62, 1085-92.) Taylor's research on rational lathe work. Detailed discussion of the Taylor's "On the Art of Cutting Metals."

1908

Comparisons of Carbon and High-Speed Drills. (In American Machinist, Vol. 31, pt. 2, p. 709-10.) Averages show that the high-speed steel drills drilled 57 times as many holes as the carbon drills.

Fabrication et Usage des Outils en Acier a Grande Vitesse. (In Revue Industrielle, p. 346, 849-50, 361-3.) Manufacture and use of tools of high-speed steel. Discussion of paper by A. L. Valentine in the Amer. Mach. includes composition of high-speed steels, analyses, tools used in tests, factors which influence the cutting speed, economic results, hardening high-speed steel, determination of the temperature, uses of high-speed steel and economics which result from its use.

Tool Steel. By F. M. Osborn. (In Iron Age, Vol. 82, p. 1612-3.) Abstract of pamphlet, a reprint of a paper before the Leeds Ass'n. of Engrs. heat-treatment after forging and grinding, results in turning tires at the New York Central Shops, making of twist drill and milling cutters from high-speed steel.

Die Neuesten Erfahrungen mit Schnelldrehstahl. By F. Ruppert. (In Zeit. des Ing., Vol. 52, p. 1611-2.) Paper on the latest practice with high-speed steel read before the Bezirksverein, chemical section, abstracted, and the discussion over

paper. Refers to Wallichs translation of Taylor's "On the Art of Cutting Metals."

Ueber Dreharbeit and Werkzeugstahle. By F. W. Taylor and A. Wallichs, translation. Berlin. J. Springer. Translation of "On the Art of Cutting Metals" reviewed in Zeit. des Ver deut. Ing., Vol. 52, p. 970.)

1909

Range of Utility of High-Speed Steel. By O. M. Becker. (In Iron Trade Review, Vol. 45, p. 4, 462-5, 507-11.) Most suitable conditions for use, use on castings, cost of tool maintenance use on reciprocating machines, milling machines and rotary planers, drills, files and small tools, in sawing and splitting, in punch work, press work, finishing and wood-working.

A Test of Novo and Novo Superior Steels. By M. I. Francis. (In American Machinist, Vol. 32, pt. 1, p. 822-29.) Testing cutting speeds, durability, tool angles on with the assistance of Mr. Winder, the inventor of Novo Superior.

A Tool Steel Testing Machine and Results. By F. G. Herbert. (In American Machinist, Vol. 32, pt. 1, p.822-29.) Testing cutting speeds, durability, tool angles, wear resistance and hardness of high-speed and carbon tool steels with a turning tool. Includes equal wear speed curves, duty curves.

High-Speed Tool Steels. (In Engineering, Vol. 107, p. 289, 347; American Machinist Vol. 32, pt. 1, p. 728-30.) Tests at Seebohm and Diechstahl's, at Edgard & Allen Co.'s, at Samuel Osborn & Co.'s, at Saville & Co., and at Nash's Test House.

Observation on the Making of High Speed Steel Tools. By O. M. Becker. (In Machinery, Vol. 16, p. 5-7.) Kind of data to preserve, hardness or temper of high speed tools, allowances to be made for variations in sizes of tools after hardening, methods of uniting high-speed steel to the tool body cutting high-speed steel, detecting cracks in high-speed steel tools, and reforging.

The Newer British High-Speed Steels. (In American Machinist, Vol 32, pt. 1, p. 586-7.) Directions given by Samuel Osborn & Co., Ltd., for hardening lathe and planer to tools, data as to endurance under cut from tests of J. J. Saville & Co., Ltd., Thomas Nash & Sons, and Spear & Jacksons, Ltd.

Some Tests of Jessop Ark High-Speed Steel. (In American Machinist, Vol. 32, Pt. 1, p. 790.) Tests conducted by the Otis Steel Co. on "Ark" high-speed steel in tools one and one-half x 3 inches, and on a Niles-Bement-Pond Co.'s tire lathe.

Some Tests of a New High-Speed Steel. (In American Machinist, Vol. 32, p. 847-50, pt. 1.) Novo Superior steel in turning and drilling tests working on forged, rolled and cast steel and cast iron. Rules for forging, hardening and grinding.

Some Good Results Obtained by Adding Vanadium to Steel. (In American Machinist, Vol. 32, pt. 1, p. 390-1.) High-speed steel tools containing vanadium machined 87 axles with one grinding, while high speed steel tool which did not contain vanadium averaged 27 axles in tests at Howard Axle Works, Homestead, Pa.

1910

High-Speed Steel. By O. M. Becker. (In N. Y. M'Graw-Hill Book Co. 360 pp.) The development, nature, treatment and use of high-speed steels. Problems involved in the use of high-speed tools, analyses of high speed and special steels, reference table for determining cutting speeds.

Unusual Results Obtained by the Use of High-Speed Steel. By C. Berg. (In American Machinist, Vol. 33, p. 676-8.) A series of tests to determine its exact cutting capabilities at the Chicago Works of the Link-Belt Co.

High-Speed Tools and Machines to Fit Them. By H. L. Brackenbury. (In Transactions Amer. Soc. Mech. Eng., Vol. 32, p. 729-51; disc. p. 771-805; Proceedings Inst. Mech. Eng. 1910, pt. 3-4, p. 929-55; disc. p. 986-1026; Mechanical Engineering, Vol. 26, p. 207-9, 216-21; abstr. Engineering, Vol. 90, p. 173-9; Iron and Coal Trades Review, Vol. 81, p. 159-60; Iron Trade Review, Vol. 47, p. 367-71.) Use of high-speed steel, detailed discussion of design and tests of machines using high-speed steel.

Etude sur les Machines Pour Aciers a Coupe Rapide. In Revue Industrielle, p. 343-6.) Study on machines for high-speed steels. Review of the use of "rapid" steel properties of high-speed steels, different kinds of steels, power necessary to cut the metal, influence of the cutting speed, cutting angle, use of high speed steel on old machines, power of modern machine tools.

The Cutting Properties of Tool Steel. By H. G. Herbert. (In Journal Iron and Steel Inst., No. 1, p. 206-42, disc. 243-5, 2 inserts, Engineering, Vol. 89, p. 691-6 extract Revue de Metallurgie, Vol. 7, p. 691-8.) Method of testing tool steel, comparison of carbon and high-speed steels, curves showing results of tests.

The Testing of Lathe Tools. By Ripper. (In Engineering, Vol. 90, p. 356-7.) Paper read at meeting of the British Association. Method of testing, durability tests of high speed steels, and speed-increment tests.

Report on the Wear of Steels and Their Resistance to Crushing. By F. Robin. (In Iron and Steel Inst. Carnegie Scholarship Memoirs, Vol. 2, p. 1-270.) P. 167. Interstrain in high-speed steels.

Tool Steels. (In Engineering, Vol. 109, p. 519-20.) Editorial calling attention to, and discussing paper of E. G. Herbert on the cutting properties of tool steels presented to Iron and Steel Institute (Journal No. 1, p. 206-42.)

1911

The Practical Use of High-Speed Tool Steel. By J. M. Gledhill. (In Mech. Engr., Vol. 27, p. 762-6.) Composition, role of different metals, melting, annealing, forging and hardening, grinding, uses of high-speed steels.

High-Speed Steel Drill Tests. By E. R. Norris. (In American Machinist, Vol. 34 pt. 1, p. 719-23.) Comparative tests at Westinghouse Co. of twisted milled fluted and forged fluted high-speed steel drills. Tungsten content does not seem to influence the efficiency in proportion to its amount.

Die Schule des Werkzeugmachers. By F. Schon. (In Hanover. M. Janecke 156 pp.) Test-book for tool-makers, p. 120-33, high-speed steel, the influence of rapid steels on the construction of tools and machines, grinding of high-speed steel tools.

Super-Vitrite High Speed Steel. (In Iron Age, Vol. 87, pt. 1, p. 282.) Performance of Super-Vitrite high-speed steel in turning shaft in the shops of Howell & Co., Wincobank, Sheffield, England.

L'emploi des Aciers Rapides et Machines—Outils a Grand Rendement. (In Revue Industrielle, p. 176.) The use of rapid steels and machine tools at great speed. Advantage of use of high-speed steel on some machines.

1912

Rolling High-Speed Tool Steel. (In Iron Age, Vol. 90, p. 67-70.) Description of electrically driven mill of the Vanadium-Alloys Steel Co., at Latrobe, Pa. Curves of the power requirements for rolling various sections.

Steels for Taps, Drills and Milling Cutters. (In Machinery, Vol. 19, p. 181-2.) High speed steels recommended for drills and milling cutters.

Vanadium in High-Speed Steel. (In Machinery, Vol. 18, p. 837.) Effect on varying amounts of vanadium from 0.2-1.0 per cent on cutting speed of high speed steel, figures given out by American Vanadium Co.

Recent Advances in Scientific Steel Metallurgy. By J. O. Arnold. (In Engineering, Vol. 95, p. 162, Mechanical Engineering, Vol. 31, p. 153-4.) Paper read before the Royal Institution, traces the development of Mushet high-speed and vanadium high-speed steels. Table gives comparative cutting powers of Huntsman's low-grade and high-grade high-speed steels.

1913

Modern Tool Steels and High-Speed Tool Alloys. By G. S. Armstrong. (In Engineering Magazine, Vol. 45, p. 833-42; vol. 46, p. 63-75, 194-200, 400-15, 931-42.) P. 883-42, theory of hardening factors conducive to cutting speed development of tool steels and alloys. P. 63-76, processes of manufacture, mechanical treatment, machinery and equipment used. P. 194-200, application of carbon and alloy steels to specific uses. P. 400-15, heat-treatment, furnaces, baths and pyrometers, p. 931-42, machine tool operation at high cutting speeds, inserts.

Tool Steel From a Salesman's Point of View. By C. M. Bigger (In Iron Age, Vol. 91, p. 706-8; Mechanical Engineering, Vol. 31, p. 380-2.) P. 707-8, high-speed steel composition and annealing and the influence of vanadium on the cutting speed and durability.

Elecobalto en los Aceros Rapidos. (In Revista Minera, Vol. 64, p. 541-2.) Cobalt in rapid steels. Brief discussion of tests made at Technical High School at Berlin.

Cutting Power of Lathe Turning Tools. By W. Ripper and G. W. Burley. (In Inst. Engrs., pt. 3-4, 1067-1141, disc. 1142-1210; Engng., Vol. 96, p. 737-56.) Tests of carbon steel and high speed steel tools, to determine the way in which the output is effected by the speed of cutting, the depth of the cut, the feed of the tool per revolution of the work, the shape of the nose of the tool, and the physical properties of the metal upon which the cutting tool is acting.

Die Fortschritte deutscher Stahlwerke bei der Herstellung hochlegierter Schneellarbeitsstahle. By G. Schlesinger. (In Stahl und Eisen, Vol. 33, p. 929-39; abstr. in Iron Age, Vol. 92, p. 33.) The progress in German steel works of the production of high alloyed rapid working steels, considering especially the effect of cobalt. Tests on cobalt high-speed tool steel at Royal Technical High School, Berlin.

1914

Aciers a Outils. By M. Denis. (In Rev. de Met. Mem., vol. 11, p. 4-94.) Tool steels. The cutting properties of tool steels following their heat treatment, and the practical utilization of these cutting properties.

Uber die Warmevorgange beim Spanschneidern und die vorteilhaften Schnitt-

geschwindigheiten. By N. Friedrich. (In Zeit. des. Ver. deut. Ing., vol. 58, p. 379, 417, 434; abstr. in Journal A. S. M. E., vol. 36, p. 0105-7.) On heat processes occurring in cutting metals and the best speeds of cutting, deals with cutting tools of high-speed steel.

La Taille Economique des Metaux par les Aciers a Coupe Rapide d'apres les Experiences de M. F. W. Taylor. By P. Massot. (In Rev. de M. et. Mem. vol. 11, p. 433-62.) The economic cutting of metals by high-speed steel according to the experiences as of F. W. Taylor.

Influence de l'emploi des Outils en Acier a Coupe Rapide sur la Construction de quelques Machines-Outils. By C. Revol. (In Rev. de Met. Mem., vol. 11, p. 357-432.) Influence of the use of tools of high-speed steel on the construction of some machine tools.

1915

Progress in Machine Shop Methods. By E. R. Norris. (In Mech. Eng., vol. 36, p. 403-5.) Development of high-speed steel, use heat-treatment, introduction of stellite. Fig. 1-2 charts showing results of tests of twenty brands of high-speed steel. Paper presented before the International Engng. Congress.

Report on Past Experimental Work on Cutting Tools. By D. Smith. (In Trans. Manchester Ass'n. Engrs. 1914-5, p. 453-653, disc. p. 653-9, one plate; abstr. Engr., vol. 119, p. 275-277.) Summary of papers on cutting tools, including Berlin Experiments with high-speed steel tools, report of the Manchester Committee 1903, High-Speed Cutting Steel by J. Niley before Newcastle & District Ass'n. of Foreman Engrs. & Mechanical Draughtsmen, 1904, papers of J. M. Gledhill, 1905-6, Univ. of Illinois Eng. Exper. Station Bull. 2, F. W Taylor, A. S. M. E. 1906, H. C. H. Carpenter in Engng. 1907 and Manchester Ass'n. of Engrs. 1908, E. G. Herbert, Iron & Steel Inst. 1910, 1912, C. P Berg, Amer. Mach. 1910, W. Carter, Birmingham Ass'n. Mech. Eng. 1910, G. Schlesinger, Stahl und. Eisen 1913, Denis, Rev. de Met. 1914.

1916

Note on the Relations Between the Cutting Efficiencies of Tool Steels and their Brinell or Scleroscope Hardness. By J. O. Arnold. (In Journal Iron & Steel Inst., vol. 93, p. 102-4, disc. p. 105-13; extract in Iron Age, vol. 97, p. 1207; Engineering, vol. 103 pp. 450-1, disc. p. 442-3; Engineering, vol. 121, p. 397-8.) No relation between Brinell hardness and lathe efficiency, table of efficiency and hardness of certain high-speed steels.

The Grinding of High-Speed Steels. By C. E. Gillett. (From "Grits and Grinds" Norton Co. in Iron Trade Review, vol. 59, p. 679-81; Mechanical Engineering, vol. 38, p. 340.) Explains causes of grinding difficulties and suggests types of wheels to use.

Tool Steel Research. Trans. Manchester Ass'n. Engrs. 1915-16, p. 421-5, disc. p. 426-371. Abstract of interim report of the Tool Steel Research Committee of tests on ordinary high-speed steels.

1917

Emploi des outils en aciers moule rapide. By Grenet. (In Revue de Met. Mem., vol. 14, p. 547-50, abstr. in Iron Age, vol. 101, p. 1204.) Cast high-speed tool steels, tests on extra hard, and normal steel at the Firming steel works.

1918

Quelques observations sur "Le Stellite." By L. Guillet and H. Godfroid. (In Revue de Metallurgie, vol. 15, p. 339-46, abstr. in Iron Age, vol. 102, p. 1584-5.) Some observations on stellite including comparison made of the variation in hardness at different temperatures of stellite and a superior quality of high-speed steel.

The New Cobalt Tool Steel. (In Iron Age, vol. 91, p. 1477.) Mention of a detailed report of extensive comparative tests of the new German cobalt steel with other tool steels, sent out by the Becker Steel Co. of America.

1919

The Molecular Constituents of High-Speed Tool Steels and Their Correlations With Lathe Efficiencies. By J. W. Arnold and F. Ibbotson. (In Journal of Iron & Steel Inst., vol. 99, p. 407-28, disc. p. 429-35, 2 plates, 1 insert, abstr. in Iron Trade Review, vol. 64, p. 1419 to 1421.) The chemical constitutions of high-speed steels, correlation of the chemical of and micrographic analyses with lathe efficiencies of the series. Note on surface tension effects in high-speed steels by F. C. Thompson.

Comparison of a Cobalt-Chrome with a Tungsten Steel. By W. J. Baxter. (In Amer. Soc. Test Mat., vol. 19, p. 161-174, Iron Age, vol. 104, p. 23.) Discussion of Dr. Mathen's paper. Results of comparative tests using cobalterom by the U. S. Navy.

Manufacture and Use of Alloy Steels. By H. D. Hibbard. J. Wiley & Sons, N Y., 96 pp. P. 68-87, manufacture, composition heat treatment, theory, testing, using and patents of high-speed steels. Bibliography.

Results of Practice at Nicetown. By G. D. Kelly. (In Amer. Soc. Test Mat. vol. 19, p. 157-9; Iron Age, vol. 104, p. 22-3.) Discussion of Dr. Mathen's paper including cutting tests, advantages of tungsten content, sweating operation.

Practical Information Concerning High-Speed Steel Abstracts. By R. C. McKenna. (In Ry. Mech. Eng., vol. 93, p. 667-8, Am. Mach., vol. 51, p. 989-91, Iron Trade Review, vol. 66, p. 148-9.) Gives composition, injurious impurities, hardening and trade practice.

Durability of High-Speed Steels. By R. Poliakoff. (In Iron Age, vol. 103, p. 295-6.) Cutting tests in nine brands of high-speed steel chemical composition, results of tests compared with Taylor's conclusions.

1920

Schnittdruck, Schnittgeschwindigkeit, Vorschub and Lebensdauer bei Gewindefrasern aus Schnellstahl. By H. Ederheimer. (In Zeitung des Ver. Deut. Ing., vol. 64, p. 149-53, transl. in Eng. and Ind. Min., vol. 3, p. 309-11.) Cutting pressure, cutting speeds, feed and life of high-speed steel screw thread milling cutters. Results of tests showing the influence of cutting feed and speed of high-speed screw milling cutters of 38.5, 48, and 53 min. diameter upon the number of cuts possible before the first regrinding is necessary, and upon the total life of the cutter. Life decreases parsbolically with increasing cutting pressure.

A Comparative Test Upon High-Speed Steels. By A. J. Langhammer. (In Chemical and Metallurgical Engineering, vol. 22, p. 829-32, p. 889-92, 939-42; Amer-

ican Machinist, vol. 52, p. 979-82.) P. 829. Current sales practices, general review of tool steel, high-speed steel stellite, influence of chemical composition, inconsistency of recommended heat-treatments, table of maker's recommendations for treating lathe and planes tools. P. 889. Conditions entering into the testing of a tool for cutting as listed by Taylor are discussed, method of eliminating most of the variables from a comparative test for the efficiency of several brands of commercial tool steel, p. 939. Detailed description of tests on 16 high-speed steels, with data as to performance, chemical composition heat-treatments and hardness.

Characteristics Treatment and Uses of High-Speed Tool Steel. (In American Machinist, vol. 53, p. 121-3.) Development of high-speed tool steels, chemical composition, special features, hardening, heat treatment and substitutes.

High-Speed Steel Tools for Turning Tires. By F. A. Stanley. (In Amer. Mach., vol. 53, p. 265-6.) Describes the tools used in the Southern Pacific shops at Sacramento for turning tires.

Tentative Specifications for Carbon Tool Steel. (In Proceedings Amer. Soc. Test. Mat., vol. 20, pt. 1, p. 502-3.) Steel to be made by crucible or electric process (except grade C), must have certain chemical composition, will be analyzed according to standard methods of analysis of plain carbon steel, permissible variations in dimensions are to be agreed upon by contractor and purchaser.

1921

Hardness of High-Speed Steel. By A. H. d'Arcambal. (In Chemical and Metallurgical Engineering, vol. 25, p. 1168-73.) Hardness of high-speed steel at moderate temperatures, hardness in the cold after various heat treatments, and cutting efficiency are determined to predetermine the usefulness of a modern machine tool.

Standardizing Specifications for Tool Steel. By C. M. Brown. (In Transactions Am. Soc. Steel Treating, vol. 1, p. 666-72.) Discusses the different types of tool steels in use and suggests seven classes for standardization purposes.

Application of Magnetic Analysis to Rock Drills. By C. W. Burrows. (In Mining and Metallurgical Engineering, vol. 174, p. 42-3.) The magnetic test indicates fatigue in the material, shows the location of the fatigue and will indicate whether reclaimation is possible.

Testing of High-Speed Tools. By Thomas Fish. (In American Machinist, vol. 54, p. 466.) Points out the necessity for standard methods of heat treating and testing of high-speed steels.

Analysis of Some Drill-Steel Tests. By F. B. Foley. (In Mining and Metallurgical Engineering, vol. 174, p. 43, 46-7.) Discusses some causes of failure of drill steel.

Metallography of High-Speed Steel. By J. P. Gill and L. D. Bowman. (In Transactions Amer. Soc. Steel Treating, vol. 2, p. 184-205.) Gives heating and cooling curves of high-speed steel, discusses the formation of compounds.

Beitrag zur Frage der Warmformgebung schwerer Blocke aus Schnellarbeitsstahl. By W. Oertel. (In Stahl und Eisen, vol. 41, p. 1413-16.) Hot working of heavy ingots of high-speed steel.

Breakage and Heat Treatment of Rock Drill Steel. By A. E. Perkins. (In Iron Age, vol. 108, p. 7-8.) Gives effect on breakage, maximum and minimum life expected and a comparison with eye bars.

High Carbon Open-Hearth Steel Versus Crucible Tool Steel in the Manufacture of Miscellaneous Tools. By G. Porteous. (In Trans. Amer. Soc. Steel Treating, vol. 1, p. 238-44.) "Just as good results can be obtained by the judicious use of open-hearth high carbon steel with proper heat treatment as can be secured from the use of a higher grade and more expensive tool steel."

When You Have Trouble With the Tool Steel You Are Using. By G. A. Richardson. (In American Machinist, vol. 54, p. 269-70.) Gives the causes that would have a bearing on the performance of tool steels in general.

Steel for Machine Tool Parts. By R. M. Taylor. (In Machinery, vol. 27, p. 770-1.) Gives tables showing physical properties, chemical composition and heat treatment of steels for machine tool parts.

Selection High-Speed Steel for Tools. By H. Traphagen. (In Transactions Amer. Soc. for Steel Treating, vol. 1, p. 527-31.) On the suitability of fracture, hardness chemical and mechanical tests for the selection of high-speed tool steel.

1922

Physical Tests on High-Speed Steels. By A. H. d'Arcambal. (In Transactions Amer. Soc. Steel Treating, vol. 2, p. 586-601.) Takes up transverse stress tests and tensile tests on 18 per cent tungsten, 1 per cent vanadium and 14 per cent tungsten, 2 per cent vanadium grades of high-speed steel.

Extent of Search

Searches 2912, 2676, 2674, 2629, 2605, 2165, 1968
Books 669.1
Ind. Arts Index 1913-20
Eng. Index 1898-20
Index A. I. M. E. 1919-20
Jnl. Iron & Steel Inst. 1900-20
Engr. 1900-19
Engng. 1900-19
Stahl und Eisen 1900-19
Rev. de Metallurgie 1904-18
A. S. M. E. Index To Trans. 1900-18
Inst. Mech. Eng. 1900-19
Zeit. des Ver. Deut. Ing. 1900-19
Genie Civil 1900-19
Revista Minera 1905-18
Bull. Soc. d'Encour. 1900-18.
Iron Age 1900-19
Jnl. Steel Treaters Research Soc. 1918-20
Trans. American Society for Steel Treating
Bull. Soc. Min. Industrie 1900-18
Revue Industrielle 1900-18
Amer. Machinist 1900-10
Iron Trade Review 1900-19
Metallurgie 1904-13
Mechanical Engr. 1900-17
Gluckauf 1900-15
Konigliches Materialprufungsamt 1900-12
Jernkontoreta Annaler 1900-17
Jernkontoreta Annaler Bihang 1900-18
Manchester Association of Engrs. 1900-19
Jnl. West of Scotland Iron & Steel Inst. 1900-19

TOOL STEEL MANIPULATION

By L. K. Marshall

IN PRESENTING this paper, under the above title, the aim will be to enumerate some of the most important points encountered in the actual practice of what may be termed scientific heat treatment of tool steel. It is the author's belief that such treatment becomes scientific when all tools, dies, etc., made in one plant are treated under the direct supervision of one head, using apparatus permitting close temperature and time control, both in the hardening and tempering operations; keeping accurate records of each piece handled, and checking up the actual performance of all tools of major importance, all of which leads to duplication of results.

Just as specialization in the tool room is fast replacing the old method of one man performing all operations incidental to the making of a tool or die; so is the method of segregated heat treatment of tool steel bound to replace the less satisfactory system of each man heat treating his own parts and pieces.

Let us follow through such a method. All pieces made in the tool room that call for heat treatment are delivered to a central point together with a delivery ticket which gives all necessary information to positively identify each piece. Each job as it is received is given a test number which is stamped on the piece or pieces where size and design permits. All pertinent information is entered on a report sheet which is made in duplicate. The report form includes data on the number of pieces to be heat treated, the material specification of the pieces, the annealing temperatures used and the method of cooling, the quenching temperatures used and the medium in which the pieces were quenched. The Brinell hardness, the scleroscope hardness and special notations are likewise included in this report form. A blank space on the right side of the form is used for making a free hand sketch of the part or parts. This idea of having a sketch as part of the report has proved its worth time and again. Inasmuch as every piece of tool steel that is to be treated is a problem in itself, each piece as received is studied and its treatment determined before it enters the furnace. It is at this stage that the hardener is confronted with his most serious work, as he now has in his hands the work of days, and oft times of weeks, which he must bring safely through the subsequent heating and quenching operations; and he must also see that the necessary mechanical characteristics, such as hardness, toughness, surface condition, etc., are as desired.

Just picture some of the problems in this connection. How numerous are the previous treatments and workings to which the steel has been subjected, over which the hardener has absolutely no control. From the time the molten steel is poured into the ingot mold, to the time it is made into a finished piece ready for heat treatment, many things may have happened to determine its behavior in the hands of the hardener. Such points as, the amount of ingot that was cropped, the amount of reduction from the ingot to the finished bar, the forging and rolling temperatures, the thoroughness of the annealing operations on the finished stock, are all beyond his control, and yet they all have a direct bearing on the finished tool as it is ready for hardening.

Each piece as it leaves the tool room is stamped with the trade name of

A paper presented before the Indianapolis Convention. The author, L. K Marshall, is metallurgist, North East Electric Co., Rochester, N. Y.

the steel of which it is made. This marking is checked against the tool drawing to note whether or not a type of steel other than that called for has been used. If a change has been made the reason is traced out before any further work is done. All pieces of major importance are touched on the emery wheel to make positive that the type of steel is as it is marked. This spark test is very important, and has at times saved much time and money by showing that a piece was oil hardening when it was marked as a water hardening steel, which if quenched as marked would obviously have resulted in damage to the piece. Every man who handles tool steel should familiarize himself with the characteristic sparks of the steels he come in contact with, and then use the information. Charts are published showing the characteristic sparks of several types of steels, but the most satisfactory way is to make two test blocks of each type or brand steel used, having one block hard and the other in the soft or annealed condition, and keep them handy to the emery wheel. It is necessary to have both the hard and the soft blocks, as a material difference may be noted between the two states. This difference is especially noticeable in some of the alloy tool steels.

In studying the work as received for heat treatment consideration should be given to the question of whether or not it has been made from a sound piece of steel, and if it will respond to the quench. This question is controlled to a certain extent through a preliminary operation, that is, by having a test piece cut from each bar as received and making routine tests on it. It is hardened and fractured, chemical analysis made of it, and if necessary photomicrographic study made of it. In this way large segregations, seams, and cracks are located, and the grain size is checked for a quench from a definite temperature. Only after these tests have been satisfied are the bars released to the stock room.

The matter of design may be controlled within the plant, as the tool designer or engineer has in his control the location of holes and fillets, and the sizes of sections. If he appreciates the hardener's position he will do all in his power to see that as far as possible each part as designed will not present any unusual difficulties. Close co-operation between the designing and tool hardening departments will go a long way towards insuring the success of the latter.

The question of annealing before hardening is debatable. It takes a lot of time and in most cases is unnecessary. If considerable stock has been hogged off, or the piece subjected to any severe working a heating to just below the critical range is carried out to reduce the dangers of cracking and warping.

Another point to be considered is the plugging of the holes. Some holes must be left open to insure proper hardening. A steel plug, either screw or rod that fits snugly is used, as both fire clay and asbestos have a tendency to blow out in the quench. All holes near the corners of a rectangular section are always plugged. The writer believes that there is a critical section around a hole, or in other words, if the proper amount of stock in relation to the diameter of the hole is left between the surface and the hole, breakage will not take place. A circular section presents much less trouble than a rectangular section.

The foregoing points all deal with manipulation before the works enters the furnace. A great deal of the breakage that occurs in tool hardening is due to uneven heating, both as to the rate of heating, and as to the final temperature reached. The necessity of even and thorough heating is em-

phasized in all text books and papers dealing with the subject of the heat treatment of steel. If the furnace is maintained at a temperature above the critical range of the piece to be quenched, the chance for uneven heating is greatly enhanced. Sharp corners, projections, and thin sections at holes are bound to reach, and often pass through the critical range, while the body or large sections are below or in the critical range. Think of what takes place; think of the strains set up. Those parts below the critical range are expanding, those in the range are contracting, and those above are expanding at still another rate. It is these strains which cause the trouble of breakage and warpage. The characteristic break due to uneven heating is a shelling off of a corner or section, generally near a hole. The electric furnace is well adapted to obtain uniform heating as the rate of heating is under minute control at all times. However ,the electric furnace is not a cure all. The same thought, judgment, and care must be exercised as in using any other source of heat.

In production heat treatment of a uniform section, a rate of heating may be found which can be used day in and day out with uniform results, but in tool hardening where the size and section is always a variable, the rate of heating is a matter of judgment of the operator. A thorough preheating to around 900 degrees Fahr., where time and furnace capacity permits aids greatly in insuring uniform heating, and also shortens the time that the piece is exposed to temperatures above a scaling heat. For parts that are not to be ground, and which must be kept clean, such as gages, mold parts, etc., this preheating has been found to be absolutely necessary. The pieces are placed in a furnace the temperature of which is below the cirtical range of the steel from which they are made. The work and the furnace are allowed to come to the same temperature, and then the heat is applied at a rate to bring the steel slowly through the critical range and as far over as is necessary. The number of degrees over the critical range to which any particular piece is heated, depends upon the type of steel of which that piece is made, and upon the work it is to do. Holding of the work at the quenching heat from 2 to 15 minutes, depending on the size of the piece, does not harm the steel as far as the writer's experience has shown.

The quench comes next. Oil quenching steels offer small danger from cracks, but are subject to warpage. These oil hardening steels are all alloy steels and must be thoroughly heated to insure perfect solid solution of constituents if maximum hardness is to be obtained in the quench. The question of water or brine quenching is also debatable. The writer has found that brine does not cause breakage, and does at times give a little added hardness. In water or brine quenching the work is never allowed to become stone cold. It is always removed to an oil bath or into the tempering furnace while the surface is still above the boiling point of water. Experience must guide this operation to a certain extent, for if removed too soon, the heat retained in the center of the piece will progress towards the surface and cause the temper to be drawn above that desired, resulting in a soft piece. The tempering operation should be carried out immediately after the quench. All work is transfered to the tempering bath at once, with the idea of getting the strains relieved as soon as possible. The tempering is not rushed from this point on. Plenty of time is allowed for the work to reach the desired heat and this temperature is maintained for a length of time depending upon the size of the piece. A piece ½-inch in section has been held at the tempering heat for as long as 1½ hours without causing softening. After the tem-

pering operation the work may be cooled in any way desired, but a safety factor is provided by placing all pieces in oil to cool.

All pieces are now checked on the scleroscope to make sure that the desired hardness has been obtained. All data pertaining to the heat treatment is now entered on the report sheet, after which the work is delivered to the tool room. The writer's experiences are based almost entirely upon electric furnace heating, with both vertical and horizontal muffle types. All high speed steel parts are treated in an electric furnace. Two preheats are given to each piece, before being placed in the high temperature furnace. These preheats are carried out at approximately 1100 degrees Fahr. and 1550 degrees Fahr. The same exact records are kept of these tools. An optical pyrometer is extremely valuable in the treatment of high speed steel tools. The furnace may be run at a slightly higher heat than the parts are to reach, and by sighting on the work it can be removed from the furnace at just the right time.

An unique use of the optical pyrometer was recently observed by the writer, in the heating of a die block. It was necessary to heat the die block in a large, semi-muffle type furnace, where the couple was at a distance from the piece. An optical pyrometer was sighted on the piece to check the readings of the couple in the furnace. As repeated readings were taken a point was reached where the furnace temperature continued to rise while the readings of the optical pyrometer remained stationary. In effect, the optical pyrometer became a transformation indicator. When this particular piece was quenched no doubts were felt but that the critical range had been passed and the desired hardness insured.

To sum up briefly, the manipulation of tool steel under scientific methods deals with the following factors:

1. A close check on the received stock.
2. A study of each piece, and the work it is to do.
3. Heating to a temperature below the critical range to relieve badly strained pieces.
4. The plugging of all holes near edges or corners, especially in rectangular sections, with steel plugs.
5. The use of great care that the whole piece passes into and through the critical range as uniformly as possible.
6. In never allowing the piece to become cold in the quench.
7. The starting of the tempering operation immediately.
8. The keeping of accurate records of all operations to aid in checking up the piece in use.

THE CORROSION OF IRON AND STEEL

By T. S. Fuller

THE corrosion of iron and steel is a very old and broad subject and one which has puzzled mankind throughout the centuries. It is on account of this active tendency of things made of iron and steel to corrode and eventually to disintegrate that the early history of the metal is so much in doubt, and that it is so difficult to determine to what extent it was used by the ancients. The pyramids of Egypt which have been standing for five thousand years were built of granite blocks probably hewn out with iron tools and records show that during blasting operations in one of the pyramids in the year 1837, a wrought iron tool was discovered. Iron is mentioned in the Holy Scriptures in connection with the date 1200 B. C., and was known to the Chinese as far back as 2357 B. C. Probably the best known classical example of ancient iron is the pillar standing at Delhi, India, said to have been erected in 912 B. C. Nevertheless, in the face of this evidence, the early history of the metal is very much in doubt because of its disappearance through corrosion and subsequent disintegration.

For many years the people in this country as well as those of other countries have heard much of the so-called conservation of natural resources movement, and of the substitution of materials which are found in large quantities for those which are less plentiful. In this movement of universal conservation of natural resources, probably no two materials are any more important than iron and coal. When it is considered that four tons of coal are required for the smelting of every ton of finished iron, and that the coal supply in the United States is estimated to be sufficient for our needs for the next six thousand years at the present rate of consumption, or for but one hundred and fifty years if the present rate of increase continues, the importance of the problem becomes immediately apparent.

To those who may not be entirely familiar with the various problems of corrosion, it may be well to state that the yellowish brown substance which forms when moisture is allowed to act on the surface of articles made of iron or steel is rust. To the person who has carefully observed and studied the mechanism of corrosion, the nature and the distribution of the rust becomes of greatest importance to him. Therefore, in order that we may all have a general viewpoint we will briefly review some of the theories which have been advanced in efforts to explain the various corrosion phenomena.

Corrosion was first considered to be a case of simple oxidation similar to that taking place when iron is heated in air. It was soon discovered, however, that not only was the presence of oxygen necessary, but also the presence of liquid water. This discovery led to the acid theory of corrosion which takes into account the necessary liquid water and oxygen, and postulates, in addition to these the presence of an acid, usually carbonic acid. The acid is assumed to unite chemically with the iron, forming a soluble ferrous salt, which is later oxidized to ferric hydrate or rust, liberating the acid radical for further attack upon the iron. By this method it is quite evident that very minute quantities of acid will be sufficient to cause corrosion.

In 1903, Whitney[1] announced the results of experiments which lead to the electrolytic theory of corrosion. Distilled water was boiled in test tubes

A paper presented before the Schenectady Chapter. The author, T. S. Fuller, is a research engineer, General Electric Co., Schenectady, N. Y.

1. Journal of American Chemical Society, 1903, 25, 394.

to expel all the air and CO_2; polished samples of iron were added and the tubes sealed while the water was boiling. These tubes were left in this manner for weeks without the slightest appearance of rust on the surface of the iron or appearance of a corrosion product on the glass or in the solution. At the end of several weeks the tubes were opened and a small amount of air admitted. A precipitate of ferric hydrate quickly settled out. Dr. Whitney's interpretation of the results of this experiment is that iron goes into solution in pure liquid water until the water becomes saturated with iron ions and a state of equilibrium is established. Until oxygen is admitted no precipitation of iron takes place. The conclusion is reached that iron goes into solution in liquid water in the absence of both an acid radical and oxygen and that corrosion is, therefore, essentially an electrolytic phenomenon.

The hydrogen peroxide theory postulates the presence of this substance as an intermediate product in the formation of rust while the biological theory regards the corrosion of iron as a phenomenon, due primarily to microorganisms.

A more recent assumption in the list of corrosion theories is that announced by J. Newton Friend, presented at a recent meeting of the American Electrochemical Society, and called by him an auto-colloid catalytic theory of corrosion. Friend regards the corrosion of iron as a colloidial phenomenon, corrosion taking place by alternate reduction and oxidation of ferric hydoxide hydrosol. This theory is of too recent origin to have attracted a great deal of discussion up to this time, and of the others only two, the acid and electrolytic theories have been seriously considered by students of corrosion. It is a very difficult matter to say which of these two views is correct, because of the difficulty of getting extremely pure substances to work with, but the writer believes that it is safe to say that ninety per cent of the students of the corrosion of iron prefer to regard it as an electrochemical phenomenon.

Considerable impetus was given to the study of corrosion by the experiments of Whitney, which lead to the electrolytic theory. Later, Cushman and Walker developed a reagent which became known as ferroxyl indicator, which demonstrates quite clearly the nature of ferrous corrosion. The indicator has been described in detail in a book by Cushman and Gardner, entitled "Corrosion and Preservation of Iron and Steel." Briefly, it may be prepared by mixing dilute water solutions of phenolphthalein and potassium ferricyanide. If a more or less permanent record is desired, the solution is thickened with gelation or agar-agar. The action of the ferroxyl indicator is this—a solution containing phenolphthalein becomes pink in the presence of an excess of hydroxyl ions; potassium ferricyanide in the presence of ferrous ions forms the characteristic Turnbull's blue compound; therefore, with the indicator in contact with an iron surface, the positive areas, for example, points where iron is going into solution in the ferrous condition, are colored blue, and the negative areas, where there is a predominance of hydroxyl ions, are colored pink by these ions. The writer suggests that those who are inclined to doubt the electrolytic nature of corrosion phenomena, try a few experiments with the ferroxyl indicator. The results are startling.

The rate of corrosion of every piece of iron or steel depends upon the individual conditions existing in the particular locality in which the metal is in use, as well as upon the means which have been taken to prevent corrosion. Bearing in mind that the two substances besides iron which are

necessary for ferrous corrosion, are liquid water and oxygen, corrosion phenomena are of many types. Iron samples, wholly immersed, corrode faster if the water is moving rapidly than they do if it is in a state of rest. The rate of corrosion of iron tanks or pipes holding water is much less if they be kept full than if they be alternately empty and full. Atmospheric corrosion proceeds much more rapidly in districts where the atmosphere is chemically polluted by sulphur vapors and the like, than it does in districts where the atmosphere is free from contamination. The corrosion of iron or steel is accelerated by contact with an element, such as copper or tin, electropositive with respect to iron, while on the other hand, corrosion is retarded by contact with an element more electronegative than iron, such as zinc. The corrosion rate increases with rising temperature. The rate of corrosion is also dependent upon the character of the steel as determined by its chemical composition and heat treatment. Steel containing small amounts of copper or nickel resists atmospheric corrosion better than pure iron. The well known stainless steels containing large amounts of chromium are highly resistant to corrosion.

The writer has found that much may be learned in a very short time about the corrosion resisting properties of a steel by observing the action of a drop of water upon the polished surface of the metal. These experiments have been described in detail before the meeting of the American Electrochemical Society in April, 1921, and will be briefly reviewed here.

Drops of distilled water in equilibrium with the air of the laboratory were placed upon various steel surfaces. In the case of pure iron corrosion began almost immediately, and at the end of a few minutes the corrosion product could be seen distributing itself, always according to the same pattern. Three distinct zones developed; an outer one, which has been termed the immune zone, an inner one, which occupied a large part of the area of the drop, and a wall zone, which lay between the outer and the inner zones. The outer zone was perhaps a half millimeter in width and the wall zone was best described as a line. The iron rust was evenly distributed over the inner zone, and was piled up to a high level on the wall zone, and the outer or immune zone was entirely free from deposits of any kind. Ferroxyl indicator showed pink over the outer zone, indicating a negative area and that at this point no iron was going into solution, and blue over the inner zone, showing that corrosion was taking place over the entire central portion of the drop. The length of time elapsing before the first appearance of rust, and the amount of rust present after the drop had evaporated, varied greatly with different steels and form the criterion for judging the corrosion resistance of the particular steel under examination.

Much has already been accomplished in the manufacture of rust resisting steels, or at least steels which rust less than pure iron, and much remains to be done. Examples are the steels containing chromium and the copper bearing steels which have been mentioned elsewhere in this paper. Of course, the ideal steel would be one having a low cost and showing no corrosion—a goal to be striven for, but probably never to be attained.

Protective coatings for iron and steel form an important section of metal technology. Various, specially prepared paints are in use, together with coatings of zinc, tin, or copper applied in different ways.

Of late much has been said and written about the deactivation of water. In general, the scheme consists in passing the water to be used in a given closed system over scrap iron, to remove the dissolved oxygen. Once the

oxygen has been removed, theoretically the water may go on circulating indefinitely in the system without corrosive action. Such installations have proved to be very successful. Iron may be made immune to corrosion by making it cathode, that is, by making it the negative pole in a cell, with a potential just sufficient to balance the solution pressure of the metal. This method is not used extensively because it is costly.

The general problem of corrosion is one which should be of the very greatest interest to all users of iron and steel; and that includes all of civilized mankind, and it is most desirable that all should have as comprehensive an understanding of the subject as possible. There are many things which are as yet unexplained, but certain facts are so well established that they may be wisely borne in mind. Therefore, in summarizing the foregoing we find the pertinent points, as follows:

1. Two substances, liquid water and oxygen are necessary for the corrosion of iron.

2. The rusting of iron may be best regarded as an electrochemical phenomenon.

3. The rate of corrosion of every piece of iron or steel depends upon its composition, upon the means taken for its protection, and upon the individual conditions existing in the particular locality in which it is in use.

4. Much may be learned in a very short time about the corrosion resisting properties of any sample of iron or steel by observing its behavior under the action of a drop of water.

It is to be hoped that the effects of those now at work on the various problems of corrosion, and the efforts of the investigators to come will help to clear up the anomalies which still stand in the way of a complete understanding of the subject.

Some notes on the Inspection of Steel for Automobile Use

(*Continued from page* 46)

time the hammer is elevated the test piece is rotated one half turn so that successive blows are delivered on opposite sides. Failure, in the form of a fatigue, progresses from the opposite sides until finally the section becomes so reduced it snaps off in tension. An automatic switch stops the machine when failure occurs and a recorder totals the number of blows. The number of blows obtained on the piece under test is compared with those previously obtained on other pieces of the same type of material which have stood up well in service and the material is judged accordingly.

Conclusion

Experience has shown that by purchasing steel from a reliable source where reasonable precautions are taken to produce sound stock, by making suitable physical tests on representative specimens, by brinelling each piece, and finally reading the individual test fracture, one can hold failures to a negligible quantity.

A NEW TYPE AUTOMATIC TEMPERATURE REGULATOR AND ITS APPLICATION TO HEAT TREATING FURNACES

By R. W. Newcomb

ALMOST every problem of automatic temperature control differs in one way or another from every other problem. The fuel that is used may be gas, oil, coal, or electricity. A great variety of burners are found, furnace construction differs, the results to be obtained may be entirely different and so on. Each installation must be considered as a separate problem. It is not difficult to design an automatic regulator which will fit one or two conditions but to make one sufficiently flexible in its adaptability and in its adjustment to fill all these requirements is another matter. This was our problem or part of it. There were certain other requirements to be met, the control over the ratio between gas and air on gas fired systems or over oil and atomizing agent on oil systems. On electric furnaces it is sometimes necessary to control the adjustment of a rheostat or to operate a circuit breaker, and sometimes to operate several series switches on the primary connections of a transformer. Many plants have all of these different conditions to meet. It was desired therefore to design a regulator which would cover the widest field and which would permit a customer to standardize on one type of machine even though he had a wide range of conditions to meet.

From the above it was not hard to lay down the fundamental specifications.

1. Dependability under which should be included accuracy, constancy, simplicity and power.
2. Flexibility in its adaptability to gas, oil, powdered coal or electricity.
3. Adjustability in that it must be possible to adjust the range, speed and magnitude of control to cover a wide temperature range and also diversified furnace and burner construction.

The element of cost did not enter into the matter in the least. In automatic temperature control it is day in and day out dependability that is wanted, the factor of cost should be and usually is the last consideration.

Two views of the machine is shown in Fig. 1 and Fig. 2. It is the result of about three years of careful development. The regulator itself is made up of four parts; the frame and bed plate; a 1/12-horsepower motor with worm and worm gear speed reductions; an escapement or ratchet mechanism and a contactor. On the ratchet wheel spindle a sprocket is mounted. This sprocket is connected by a sprocket chain to another sprocket wheel attached to the valve or other appliance which is to be regulated. In case gas and air or several valves are to be regulated at once then this connecting sprocket chain runs over each of the sprockets mounted thereon. When either one of the solenoids is energized, then one of the pawls of the escapement mechanism engages with the ratchet wheel and moves it in one direction or the other depending upon which pawl is engaged. The movement of the ratchet wheel depends upon the setting of the wrist pin in the cam. It can be set to pass only one ratchet tooth each vibration of the escapement lever or up to a maximum of four teeth. The total angular movement of the ratchet may be limited to 220 by filing away four consecutive ratchet teeth. By selection of the proper sprockets this can be made to correspond to fully open and fully closed valve positions.

A paper presented before the Indianapolis Convention. The author is connected with Charles Engelhard, Inc., New York.

The escapement lever vibrates in one direction about once in five seconds. If the wrist pin in the cam is set so that only one ratchet tooth is passed each vibration, and if the solenoid controlling the pawl is energized for five seconds, then the ratchet spindle movement will be 1/50th of one revolution for there are fifty teeth on the ratchet. If the sprocket ratio from regulator to valve is 1 to 8, then the valve is moved 1/400 of one revolution. This is a much finer adjustment than is possible by manual control. If the solenoid is energized for 10 seconds, double the adjustment is made for then two vibrations of the escapement lever are effective. As soon as the solenoid circuit is broken, the pawl takes up a neutral position and no further adjustment takes place until one or the other of the two solenoids is again energized.

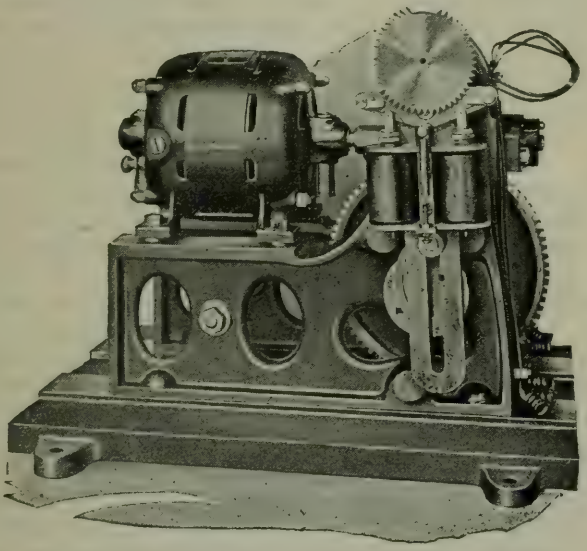


Fig. 1—Shows one view of regulator control mechanism.

From this can be seen that the speed of control is not only a function of the setting of the wrist pin and of the time during which one or the other of the solenoids is energized, but also the frequency with which one of these solenoids is energized. In other words, if a solenoid is connected in circuit only for five seconds once in 12 minutes and otherwise as given above then the valve adjustment can only be 1/400 of one revolution in twelve minutes. If the solenoid is energized once every half minute then the speed of adjustment will be 24 times as fast. Carrying the possibility of speed control to the other extreme, if we have a sprocket ratio from regulator to valve of 8-1 instead of 1-8, if the cam wrist pin is set to increase the amplitude of movement on the pawls so that four ratchet teeth are passed each vibration, if the solenoids are energized for twenty seconds and if they are connected in circuit once in 40 seconds then the speed of valve control will be 3.41 revolutions of the valve every 40 seconds. This entire range of adjustability from 1/400 of a revolution in 12 minutes to 3.41 in 40 seconds is equivalent to 24532 per cent.

The solenoids are controlled electrically from the maximum and minimum contacts in the temperature measuring instrument. When a thermostat

serves for this purpose then the neutral lead connecting it to the solenoids is connected in series with a contactor. This establishes the circuit at certain intervals and for a certain length of time only. Both the interval and the period are adjustable. The former between limits of 40 seconds and 12 minutes, the latter from 0 seconds to 40 seconds. The contactor is mounted on the opposite side of the regulator away from the cam.

When an electric thermometer or thermo-electric pyrometer serves as a measuring instrument, then the contactor works in a little different way. The maximum and minimum contacts are in the form of arced plates electrically insulated, separated by a very narrow gap and counted on the scale of the instrument in such a way that they can be adjusted to almost any point on the temperature scale. The pointer swings above them. It is provided with a platinum point vertical to the contact plates. Above the pointer and bent to correspond to the arc of the scale, a chopper bar is pivoted. This chopper bar is controlled by a small solenoid within the instrument case. It is connected to the neutral circuit of the solenoids on the regulator while the maximum plate contact is connected to the other side of one regulator solenoid and the minimum plate to the opposite side of the other regulator solenoid. From this can be seen that to energize either regulator solenoid the chopper bar drops and presses the platinum point in the instrument pointer down against one of the contact plates beneath. This completes the circuit to one of the solenoids. If the pointer was above the minimum contact plate then the valve is made to open slightly. If it was above the maximum plate then the other regulator solenoid is energized and the valve is closed slightly. The interval at which the chopper bar operates and the time during which it is down is the main controlling factor as to speed of adustment before mentioned. Therefore, if we connect the solenoid which controls the chopper bar to the contactor on the regulator, we can adjust these functions over a wide range.

Another important point aside from this great range of adjustability is that the whole apparatus is entirely automatic. There are no clocks or other parts which could introduce complications. The greatest advantage in this type of regulator compared to those that operate on a bypass and are either all open or all closed, is that it operates to correct wrong tendencies rather than extremes of high or low temperature.

You may be asked what is the advantage of a control which so operates, that it slightly increases or decreases the heat as compared with one operating on the fully opened and fully closed principle if the latter apparently do control furnace temperatures within the same temperature limits. The answer is this. Is it not logical to suppose that with enough fuel controlled through a bypass on the "all off" and "all on" system that there is enough under control to take care of pressure variation, clogging burners, opened and closed doors, etc., that with such an amount of fuel, that when the valve is opened the temperature rapidly increases, whereas, when the valve is closed there is a comparatively fast dropping off of temperature. The lag of the furnace and of the thermocouple enters in to such an extent that while the thermocouple may show a control within narrow limits, actually there is a much greater fluctuation in the area nearer the source of heat. When the regulator is capable of making a very slight adjustment and then only when required, and at the same time has a range to more than cover the extremes of temperature required, then the curve of furnac temperature instead of being a saw toothed affair, which does not in all proba-

bility indicate the actual extremes of heat, becomes more of a waved line, indicating a uniform furnace temperature throughout.

On oil fired systems the bug-a-bear of automatic regulation is clogged burners and change in the viscosity of the oil. With the regulation described they are handled the same as they would be by manual control. When the temperature drops for any reason clogged burners, lower viscosity or a drop in pressure the machine simply proceeds to open up the oil, and the air or steam valve and in exact accordance with a predetermined ratio.

On electric furnaces controlled by taps of a transformer it is possible to replace the usual knife switches or breakers with a controller which is of rotary form with carbon contacts. With the adjustability and flexibility provided, the same machine can be made to fit almost any condition of control, without changing its construction. It is only a question of properly

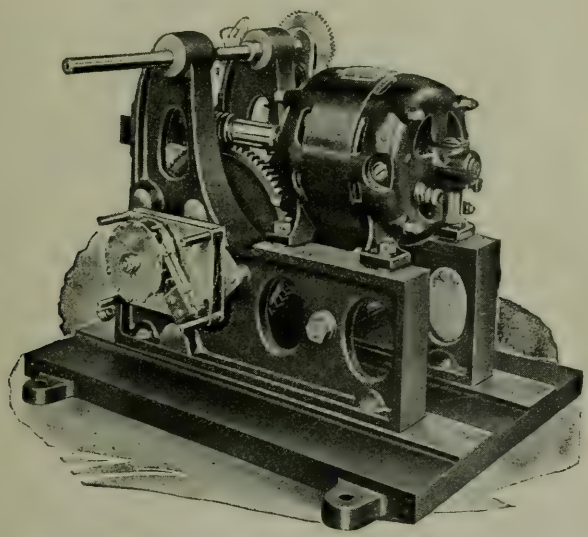


Fig. 2—Shows the opposite side view of regulator control

relating the size of the sprocket on the machine to the sprockets on the rotatable member which is to be controlled.

It needs hardly to be explained that the sentivity of the measuring instrument, the lag of the thermocouple and the location of it in relation to the source of heat, are factors of much importance. However, it is sufficient to say that the lower the range the closer the control as a rule, in terms of degrees. A very sensitive control is obtained through the medium of a thermostat for a range up to 300 or 350 degrees Fahr. For the range 350 degrees Fahr. to 1300 degrees Fahr. a differential instrument can be used in connection with the resistance thermometer. This makes possible a full scale range on the instrument of plus and minus 50 degrees Fahr. or less. When so calibrated very close regulation is possible.

An equipment is now under construction upon which a guarantee of control within plus or minus ½ of a degree Cent. has been given. Under ordinary conditions in a well designed furnace it is possible to control with

an accuracy of plus or minus 10 degrees Fahr. This limit is given on average furnace temperatures and not on control as indicated by the thermocouple used by the control equipment itself.

Particular notice is directed to this, inasmuch as a curve plotted from temperatures shown by this couple will almost always show a close control, if the instrument and regulator are sensitive. It is average furnace temperature that counts and it is the writer's contention that a better and more uniform temperature control is obtained when the regulator makes only the very slight adjustments necessary to carry an even heat.

To obtain the same effect from a system operating on the "all on" and "all off" principle then such a very small amount of fuel is under control as compared to the total amount used that a great deal of time is lost in bringing the furnace up to heat after a new charge is put in. In any case the amount of fuel under control must be enough to take care of any change in pressure to which the moving system may be subjected.

Before closing this paper the writer wishes to mention the system of automatic regulation of temperature along a predetermined time-temperature curve. This is much more difficult and complex than when regulation at a fixed temperature is wanted. Several instruments have been designed and patented for this purpose. The main difference between them and those for control at a fixed point is that the maximum and minimum contacts have to be moved across the scale in accordance with a certain time curve previously determined. Some do this by using a cam driven by a small motor or other power. This cam is connected in such a way that the contacts are advanced a certain number of degrees at a certain time rate. This rate need not be represented by a straight line curve. The instrument used with the regulator above described has its maximum and minimum contacts in the form of thin plates mounted around a drum. They are electrically insulated from each other and are separated by a narrow gap or line. If these contacts were laid out flat, this gap would be the curve of the temperature control desired. The drum is driven at a certain speed, therefore, the gap between the contact plates on the drum just beneath the pointer is constantly changing its position. In other words, the point at which control is obtained is constantly changing and in accordance with the time temperature curve laid out, is represented by the gap separating the two contact plates. It is as easy to change drums as it is to change a phonograph record.

When the regulator described in this paper is used to control the temperature of a furnace according to a time-temperature curve it is as capable of close control at the lower range as at the higher range, because the units or magnitude of each adjustment is the same in either case.

STEEL TREATERS—"WE ARE GUILTY"

By Edmund Blasko

SEVERAL criminals were on trial in New York the other day and the conscience of one of them was worrying him so much that he confessed. He became the chief witness for the State and as a reward, the charges against him were dropped and guilty though he was, he escaped punishment.

So is my conscience troubling me. We are not on trial yet, but you can hear charges against us. It is mostly inefficiency of heat treating equipment and slow progress. Heaven knows but they sound rather familiar. I feel somewhat uneasy. I believe I'll confess and offer the evidence voluntarily.

Steel Treaters, we might just as well all confess, "We are guilty."

We are guilty of inefficiency.

We are guilty of slow thinking.

We are guilty of having faulty heat treat layouts, of using unfit transportation methods.

We are guilty of negligence.

Have you ever had a device made, of which you just had a faint idea how it will work?

Did you ever try some instrument in a furnace which did not work very well when the furnace was cold, nevertheless, you thought it may work when the furnace is heated up?

Did you ever quench steel heated well above or below the temperature it should have been heated, thinking it would be good enough?

Did you often try to put something over the metallurgical department by changing the standard heat treatment of steel; and you thought it was all right, because you got away with it?

Do you feel guilty?

We are guilty of using obsolete furnaces, of indifference to progress, of not giving a fair chance to new developments. Sometimes you see a worthy implement at the Convention exhibition that has never been given a thorough test and so does not find its way into general use.

We are guilty of a naughty sin; of being satisfied with ourselves, not to say proud of ourselves.

Why, some of us pride ourselves of being able to make a piece of steel hard and a hard one soft, though in neither case may the steel be in the right condition; and many of us feel proud of being able to build a heat treating furnace, though it may not be possible to heat it anywhere near uniformly.

We hear of others progress, but just as if we were nailed down, we stand still—we don't follow them.

As you see our sins are numerous, though these may not be all.

If you feel guilty of some of these or of some other sins committed against common sense heat treating, bow your head, put ashes on it and re-

A paper presented before the Indianapolis Convention. The author, Edmund Blasko, is connected with the Ford Motor Company, Dearborn, Mich.

pent, for you sinned against your common sense. May the God of steel treaters forgive you.

We feel better after our confession. We ought to. To realize our faults is half removing them. It should not be very hard to get rid of the rest. Yes, we have made many mistakes—we did not excell in our first attempt, but we will have a new chance. We will build a new heat treat, profiting by our previous errors and we will equip it so as to avoid the many mistakes we made before. We will have an opportunity which few of us have: To do it over again.

Suppose we have an opportunity to build a heat treating department as part of a manufacturing plant with a fairly large production, automobiles for instance. We will only consider the production heat treat and not a complete layout even of that, just rough it out. Let us try to use our much valued but less used gift: Our common sense.—

First of all we have to make a preliminary layout of the heat treat and also of the shops where heat treated parts are machined, as they are so closely related to each other that we should never make a layout of one without considering the layout of the other at the same time. To make a general layout, one should possess power of imagination, one should be able to visualize the continuous flow of material in all the shops, then put his vision on paper.

As labor is the most expensive item in heat treating, the first consideration should be the elimination of manual labor as much as possible in every production heat treating department. First of all, eliminate labor in the transportation of the parts from the machine shop to the heat treat and vice-versa. The general practice is to put up a separate heat treat building somewhere near the machine shop and truck the heat treated parts to and from the heat treat. But is this right? No, by no means. The machine shop will certainly be laid out so that all parts, while being machined will advance in one general direction, that is toward the assembly, with the aid of a conveyor system. Why should the heat treating department be an exception to this rule? It should not be. Some of the parts will be heat treated before machining and some both before and after machining. Some of those that are heat treated after machining will have to come in the machine shop for grinding.

It is evident that if we put the heat treating department in a separate building, it will require several transportations between the two departments. This is very inefficient. The solution is that the heat treat should be in the path of the machining operations to harmonize with the rule that the machined parts—in order to avoid unnecessary transportation—should advance continuously towards one point, the assembly or shipping, whatever the case may be.

This will, of course, divide the heat treating department in two parts; a heating department for parts before machining and one for parts after machining. The first will include the annealing of all parts before machining; also the hardening of those forgings that are drawn at a high enough temperature to permit their machining. The second which we may call the hardening room will be for the hardening of all machined parts. The two heat treats are separated by that part of the machine shop, where the heat treated parts are machined. Next to the hardening room should be located the grinding room where the grinding after hardening is done.

The layout should be such that on stock conveyor (with several drives if necessary) would carry the parts from the annealing room to the ma-

chine shop, from there into the hardening room and then into the grinding department. This arrangement may be unusual, but it is the correct one. Why should the annealing for rough forgings be carried out in the same room with the hardening of finished parts? We never think of sorting the lathes, millers or drill presses in a production shop, so why should we keep the annealing and hardening rooms together? The separation cuts the transportation cost to a fraction of what it would be by sending the parts back and forth between the machine shop and heat treating department. There is no reason why we should harden the parts in the same room in which we anneal them, in fact, there are some who believe that the furnaces should be scattered in the machine shop, each furnace built for certain part and placed in its respective department.

This would hardly be the right solution though. It requires too many small units and the more and smaller units we have, the more inefficiently we work. Also the floor space required with such layout would be many times that of a concentrated heat treat. The machine shop would be encircled with a number of different pipings and if any of the furnaces would be out of order, it would be rather difficult to heat treat those parts in other departments. There might be a reserve furnace in every department, but its cost would prohibit this, while in a concentrated heat treat, it is not difficult at all to provide a reserve furnace unit. Therefore, those parts of the heat treat that do the same kind of work should be concentrated but located properly in relation to the machine shop to insure cheap transportation.

Next we have to plan the annealing room. For annealing in large production, we should not consider anything but continuous furnaces. They relieve the furnace operator of quite a lot of work and thus make it possible for him to handle much larger tonnage per day. Continuous furnaces satisfy the proper heating better than the old square furnace with doors at the front. The heat is more uniform. There is a gradual increase in temperature from the feeding end to the unloading end. The furnaces can be built in much larger sizes without being awkward to handle. Every part of the furnace is approximately at constant temperature, which saves the furnace and insures for every piece the same rate of heating. It makes the work less difficult for the men, which in turn means a savings in labor. Also it is much easier to hold the heat constant, as it requires but little adjustment on account of the constant uniform feeding. It saves floor space. In fact anywhere where production allows its use, its advantages are so obvious that it prohibits the use of the old square furnaces with doors at the front only.

Continuous furnaces require some mechanical device to move the pieces through the furnace or if it is an inclined furnace for round stock, a stop device that holds them and lets out a certain number each time. Some steel treaters seem too prejudiced against all kinds of mechanical devices on heat treating furnaces; undoubtedly the chief reason for this is their unfortunate experience with a few inefficient devices. Some of them made up their minds that no device will work with a furnace, but the right ones will. There are many of these continuous furnaces in operation and most of them are very successful. The capacity per square foot of space it occupies is several times larger than one of the larger furnaces. Of course, we should not adopt them unless production warrants their use. We should build as large annealing furnaces as production permits. The annealing room will also include the hardening and drawing furnaces for those forgings that after being hardened are drawn at a high temperature to permit their ma-

chining. The forgings should be lifted from the quenching tank by means of a conveyor and deposited at the feed end of the drawing furnace or taken through the drawing furnace with the same conveyor. After the forgings leave the annealing or drawing furnaces, they may be allowed to cool on the floor, but most of them can be cooled in luke warm water right away. Dropping them in water from a temperature below 1000 degrees Fahr. does not effect their hardness, but it makes their cooling uniform, besides facilitating their handling a great deal, as the forgings can be handled with gloves and thrown on the machine shop conveyor without the necessity of piling them up inside or outside of the heat treat at the cost of additional transportation.

An annealing furnace 42 inches wide inside and 20 feet long with a 7-foot long heating chamber would have a capacity of approximately 1500 pounds of forgings per hour, or 18 tons in 24 hours and the same size hardening furnace about 1000 pounds per hour or 12 tons in 24 hours, as the pieces could not be piled up in it. So to take care of about 36 tons of annealing and 24 tons of hardening and drawing, it would be sufficient to install three annealing furnaces—the third one as a reserve, and three sets of hardening and drawing furnaces, including one reserve set to be used while some of the other furnaces are in repair or to catch up with the production occasionally. As for the fuel used in the furnaces, that depends on plant conditions entirely. Electric furnaces may be prohibitively expensive in the annealing room, but they certainly should receive first consideration in the hardening room. The hardening department receives the parts from the machine shop on the same conveyor. This is where we need a great deal of improvement, as here it is where our inadequate and improper methods stand out boldly as a monument to our inefficiency. The bulk of the work in the hardening room of an automobile plant consists of gears and this is what I have mostly in mind.

You can see all over in heat treat departments how they harden gears and other finished parts in air furnaces. Of course they get scaled. To remove the scale they brush, sand blast or tap them with small hammers. Usually we get away with this scale unless there is a key way, splines or some threaded section on the pieces but once in a while with a little carelessness this scale cannot be removed and we spoil thousands of pieces this way. There are some electric furnaces that reduce scaling to a minimum, but they do not entirely eliminate it, the parts must be cleaned from the scale.

After the scale is removed, the parts are drawn in semi-muffle furnaces or in oil baths, depending on the drawing temperature.

New type furnaces should be developed for the hardening of finished parts, such as gears. We should be able to eliminate the many operations and numerous handlings. The future furnace should be a continuous furnace with automatic feed and discharge capable of a fairly large production and of such construction that will allow parts to be quenched in any position desired. Also as a step further, it should be built in combination with drawing furnace. This might be air drawing furnaces instead of oil baths. It really should be an electric furnace with an automatic temperature regulator, so that one man could handle three or four of these furnaces. The furnace

must be as scale proof as possible. This is the coming furnace for finished parts, but, of course, it should be sold at a reasonable price to insure wide use.

Many of us think that electric furnaces are an expensive luxury. There may be some cases where they are, but in many cases, the cost of heat treating could be made actually cheaper by using electric furnaces. Even if the power rate is high, the possibility of reducing labor expenses, would compensate for the additional cost of operation. Electric furnaces are very easily adapted to labor saving devices, and automatic equipment.

In conclusion the writer wishes to point out some of the defects in our heat treating methods which could be improved upon. To eliminate them we need more thinking, more fresh ideas. We have to think, think and think, then get together and exchange ideas. We should have frequent round table talks. We should experiment, do development work side by side with our every day work and let others know the results. It is only good common sense policy; the next one will continue where we left off, instead of starting it all over again. Spread your knowledge liberally, as it pays.

Do not fear to tell what you know, for secretiveness will prevent you from acquiring additional knowledge. Individuals alone can make but slow progress. We need the help, encouragement and criticisms of others. We have to know what others think of our ways. This does not necessarily mean that we have to follow their views, even if no one agrees with us—after all, our ideas may not be correct and righteous criticism will be helpful. If problems come up in regard to heat treatment, talk it over with others in the department. Listen to different opinions no matter how much better you may think your suggestions may be. It will serve a double purpose. First, they may have very good suggestions that will help you, second, this will encourage them, stimulate their desire for more knowledge and force them to think.

All that is written above could be put in a few words; ACQUIRE AND USE YOUR COMMON SENSE. You may have it by birth, but you can acquire it by study. A man blessed with common sense, ambition to learn and willing to work, can do anything.

You need common sense in your everyday work, you need it in your every day life. It is so simple; still there is something awe inspiring in it. We admire it in others, and the knowledge that we can acquire it brings it close to us. If we could ever re-create the ancient gods, we should create one for common sense. It is worth anything to acquire, as it is worthier than riches, more useful than genius, the greatest gift you can be blessed with: COMMON SENSE.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

NEW QUESTIONS

QUESTION 46. Is the practice of buying high-speed steel by brand names instead of physical, chemical and metallurgical specifications justifiable?

QUESTION 47. What is meant by "secondary hardness" in the tempering of high-speed steel.

QUESTION 48. What are dendrites and how may they be detected?

QUESTION 49. Can dendrites be removed through a proper heat treatment?

QUESTION 50. What is the chemical composition of the so-called "stainless steel" used for cutlery purposes?

ANSWERS TO OLD QUESTIONS

QUESTION NO. 27. What is the function of the high phosphorus and the high sulphur content in the so called automatic screw stock steel?

QUESTION NO. 30 How do the physical properties of a chrome molybdenum steel vary from the physical properties of a chrome vanadium steel after suitable heat treatments have been given to each?

QUESTION NO. 32. In choosing a carburizer, what are the essential features that should be considered?

ANSWER. By C. W. Bell. Lately there has been a good deal said about the energizers, kind of charcoal, kind of coke, etc., which are best for use in the manufacture of a carbonizer. The man who uses the material is not interested in how it is made but in the results which it gives him. Therefore, in testing the merits of different compounds, the one which gives the desired case and carbon content in the quickest time and which repeats these results day after day and at the least cost, is the best compound regardless of the kind of energizer it contains or the source of its charcoal.

Therefore, in choosing compounds, tests should be run to determine which compound produces the desired results in the quickest time, and

this can be ascertained by running the different compounds in the same sized boxes, containing the same number and size of steel pieces, packed in the same furnace and inspecting the results for depth of case and carbon content.

This test should be repeated for each compound time after time and inspections made of the pieces after each heat. The compound giving repeatedly the same depth of case and carbon content will prove its reliability.

It is customary in production to use a compound in the proportion of one part of new to three parts of old. Therefore, in making test runs this same proportion should be followed. By keeping account of the total weights of new compound used in the above tests and figuring these weights at the cost per ton, the most economical compound to use can be easily ascertained. The compound which is superior in these three points of efficiency, reliability and economy should be the compound selected, regardless of the energizer used.

Some compounds are very dusty when received, some of them generate an excessive amount of dust in use, some of them have both of these drawbacks. The compound which is clean and produces the least amount of dirt in use is very desirable and this point should be given very careful consideration.

To summarize; select the compound which gives the results you want in the quickest time repeatedly at the least cost and which is the least dusty. There are other points of minor importance but these are the most essential.

QUESTION NO. 35. *What is the difference between red annealed and blue annealed sheet steel?*

QUESTION NO. 38. *What regulations are recommended to reduce the fire hazzard of quenching tanks?*

QUESTION NO. 40. *What is the influence of a low percentage copper content in steel?*

ANSWER.—Numerous and varied statements have been given in reference to the beneficial effects of a low copper content in a steel. The chief benefit, apparently is that it retards atmospheric corrosion. It has been stated, however, that a copper bearing steel is not particularly resistive to salt water. The copper content is usually less than 0.30 per cent and this addition to an ordinary steel does not apparently interfere with the tenacity or ductility of the steel.

Severe corrosion tests made by various research organizations have shown a marked superiority in the resistance of the copper bearing steels over the non-copper bearing ones as well as wrought iron. Such a steel has been reported to outlast similar steels without copper from 3 to 5 times. An ordinary steel having a high sulphur content is usually less resistive to corrision than a lower sulphur steel, however the presence of copper up to 0.30 per cent appears to neutralize the bad effect of the sulphur. A copper content of 0.10 per cent will neutralize sulphur up to 0.05 per cent.

QUESTION 41. *Is the X-ray examination of steels commercially practicable?*

QUESTION 42. *Why should high speed steel be delivered only in the annealed condition?*

ANSWER. High-speed steel should be delivered only in the annealed condition because annealing relieves the internal strains inevitable in the manufacture and puts it in vastly improved physical condition. The manufacturer's inspection after annealing also discloses defects not visible in the unannealed state.

QUESTION 43. *What is the role of Chromium and Vanadium in steel?*

ANSWER. From a paper by F. J. Griffiths presented at the Twentieth annual meeting of the American Society for Testing Materials.

Chrome-vanadium steel holds the position virtually at the head of the commercial alloy steels, and owes this prestige to the extremely wide range of physical qualities which are capable of being developed from this metal by proper methods of heat treatment. Like all alloy steels, it is as its earlier name signifies, a special steel, meaning not only that it is designed for special purposes, but also that its preparation for the particular work it is called upon to perform must be carried out along certain lines calculated to yield in the final result, those qualities which shall represent 100 per cent efficiency in the final product. Many specifications today allow a variation of 1 or 2 per cent in the elongation, and restrict also the ultimate strength and yield point to extremely narrow limits. Examination of these specifications alone would serve to show the wide range of qualities of chrome-vanadium steel, and the absolute delicate accuracy with which by proper management it may be put into condition to perform its highest functions.

Chrome-vanadium combines in such a manner with iron that the separate constituents of the final alloy produced cannot be distinguished, regardless of the methods selected to separate them. Whether we adopt mechanical means or use the microscope under high magnification the result is the same; the discovery of a homogeneous blending of the allied elements which defies detection of the constituent substances. This phenomenon indicates a quite strong combination between the alloying elements and defines the combination unmistakably.

It is generally recognized that when one metal alloys with one or more other metals, its poperties are changed in a remarkable manner. The fusion may be lowered, the hardness and strength increased, the ductility affected proportionately and the transformation temperatures raised or lowered, depending upon the nature and characteristics of the alloying elements. Therefore, by properly alloying a metal, the properties of the resulting alloy may possess such profound qualities as to render it more adaptable for the purpose for which it was originally intended. It is the endeavor to decrease injurious properties and to increase the desirable ones. For this fundamental reason, the iron alloys have become to a considerable extent standardized. Those better known to metallurgy and fabricators are the nickel and nickel-chromium steels. Until recently, little investigation has been ventured to ascertain the definite properties of chrome-vanadium, and the advantages secured by this alloying element were relatively unknown ex-

cept to a favorite few, who, through their own research work, acquired intimate knowledge of the characteristics bestowed upon iron by the addition of this alloy.

Chrome-vanadium alloys with iron in all proportions and affects the properties to a marked degree, depending upon the percentage of chrome-vanadium present. The qualities which become inherent are influenced also more or less proportionately by the amount of carbon contained. In this respect chrome vanadium steel is a special steel in another sense of the word, and cannot be judged by the same standard as the old carbon steels.

The point of view of the examiner of the old commercial steel is always that of the actual condition in which the metal exists as he sees it before him, and governed by the amount of carbon present. But this point of view has altered gradually until with chrome-vanadium steel, the carbon range permissible to obtain specific characteristics has become narrowed. The presence of chrome-vanadium in steel intensifies the effect of the carbon in all the best qualities, which it is capable of producing alone. These increases take form not only in physical results, dynamic strength, resistance to wear, increased hardening power, lack of brittleness, etc., but also in purity, soundness and homogeneity of the metal. These are the specific contributions which chrome-vanadium brings to iron as compared to the older simple steel.

Unfortunately many of these qualities enumerated have no current and accepted method of measurement, whereby they may be offered on a basis for comparison. Figures may be, and often are, offered to show accurately the result of comparative tests which are intended as a means of comparison of the functions of a particular steel, but, ordinarily, the test conditions would vary so much under the manipulation of other experimenters that no comparable results are really obtainable. In any event, the data submitted usually mean nothing to the other man.

The property of soundness of the casting and ingots, produced by the use of chrome-vanadium, induces freedom from occluded gases and greatly increases the desirable physical qualities of the forgings subsequently made from this steel, such as strength, ductility and resilience. These desirable properties are amply proved not only from the results obtained from tests, but also from the more vital trial of actual use. The user of an alloy steel is concerned entirely with what ultimate qualities the metal is capable of developing, regardless of the experience with which he may have previously contended.

According to the old view and judging from the results of tests, chrome vanadium steel, as rolled or annealed, may appear to be a worthless product. It may have a percentage of elongation, reduction of area, elastic limit and ultimate strength corresponding to simple carbon steel. Stress is laid on this particularly because there is still a large and unreasonable prejudice in certain quarters against the use of steels which have to be put in special condition, or more plainly, heat treated, before they are capable of doing their best work. Of course, as we all know, this feeling is largely giving way before the splendid performance which steels of this character are giving in service, and given

sufficient time, the special steels themselves will demonstrate the unsoundness of this objection, based largely upon the limitations of the older simple carbon steels.

One of the principal effects produced in steel by the addition of chrome-vanadium, is to raise the temperature at which the carbides dissolve in the iron, and the temperature at which they are precipitated out of solution. This elevation of the solution temperature is quite noticeable, the carbon content affecting this temperature but slightly.

It is unnecessary to point out the practical utility in commercial practice of working with a steel, in which this slow rate of transformation can be taken advantage of by the use of higher temperatures without resulting injury to the product, and also by the fact that the steel can stand exposure at these higher temperatures without the attendant harmful effect characteristic of other steels subjected to the same conditions. In fact, chrome-vanadium seems to attain its greatest combination of desirable qualities at higher treatment temperature than would be expected from the location of its critical range, due principally to the greater length of time necessary to effect the complete transformation of its constituents into a uniform and homogeneous solid solution. This point is emphasized because certain other commercial alloy steels, although excellent in many respects, have very narrow limits of annealing and hardening temperatures, and therefore require unusual care in their treatment, a slight deviation from the correct temperatures resulting unsatisfactorily.

A single quenching and drawing treatment, is sufficient for general purpose to effect complete refinement and hardening of chrome-vanadium steel. This characteristic of simplicity in treatment obviously insures a high-grade product under ordinary commercial conditions, and when compared with the double and triple heat treatments required for the refinement of other alloy steels, the economy presented is obvious. These properties, possessed only by the chrome-vanadium alloy, characterizes this steel as a material universally applicable for any commercial requirement. They also simplify the treating instructions necessary to successfully handle alloy steel of this chemical composition. One heat treating specification is adaptable for any carbon analysis, whether the steel is destined for case-hardening purposes or for oil-treating for gears and cones, etc. It has been found by experience that a temperature of 775 degrees C., which is suitable for hardening a case-hardening steel and still retain desirable toughness of the core, can also be employed for hardening oil-treated parts.

The lower-carbon chrome-vanadium steels are apparently pearlitic in nature and, as such, possess the increased strength and hardness resulting from the effect of the special elements in producing a ferrite of superior strength, subsequently resulting in a more dense and improved pearlite. With the increase in the carbon and alloy contents, this steel becomes more or less cementitic and it is probably this quality which demands the use of higher temperatures than usual in treatment in order to produce complete absorption of its component parts.

The quality of chrome-vanadium steel often described as "tough hardness" is one of its especially desirable properties, and is due probably to the somewhat finer and denser structure of the microscopic constituents, and to their more uniform distribution. This effect is ob-

tained not only through the actual influence of the chromium and vanadium as component parts of the alloy, but also to the influence of the combination of both of these elements in producing in the molten metal a condition of purity and freedom from gases, and, therefore, subsequently forming a metal which, at the time when the structural changes occur, is in the best possible condition for these changes to take place, that is, in the highest form in which the alloy composition renders it possible.

The adaptability of chrome-vanadium steel is general, and where strength and hardness and resistance to fatigue properties are the prerequisite, there is a chrome-vanadium steel for the purpose. When the steel is case hardened, a glass-hard surface and tough fibrous core is easily obtained. These properties are obtained without complex treatment, consisting of simple quenching, with reheating and quenching. For other heat-treated parts, a simple heating, quenching and drawing gives a steel, relatively so tough and strong, that it is unlike any other hardening alloy steel. Chrome-vanadium steel is a universal alloy steel and stands forth unmistakably as the master alloy.

QUESTION 44. *Is it advantageous for the purchaser to conduct a test on various brands of high speed steel before deciding upon placing his contract?*

QUESTION 45. *What is the value of testing finished tools with a file?*

ANSWER. The value of the file test depends upon the quality of the file and the intelligence and experience of the person using it. The file test is not reliable, but in the hands of an experienced operator, gives some valuable information. The manufacturer of small tools from high-speed steel sometime carriers the file test to extremes. Almost every steel treater knows of numerous instances where a lathe tool which could be touched with a file has shown wonderful results as to cutting efficiency.

Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Criticism in This Column—Members Submitting Discussions Are Requested to Give Their Names and Addresses

A. S. S. T.

A RECENT communication received from one of our members enclosed the photograph which is shown below and which was taken "somewhere in Ohio." This photograph is interesting from the point of view that there are other materials beside steel which are being case hardened and we are wondering just what the name of a Society covering this activity would

be. It is possible it would be known as the American Society for Stone Treating (A. S. S. T.) The process involved in imparting a surface hardness to stone truly must be quite interesting.

News of the Chapters

SCHEDULED REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Cleveland—Fourth Friday, Cleveland Engineering Society Rooms, Hotel Winton; meeting at 8:00 p. m.

Detroit—Second and fourth Monday. For meeting place call W. G. Calkins, Sec'y. Detroit Twist Drill Co.

STANDING OF THE CHAPTERS

In the July issue of TRANSACTIONS was published the standing of the chapters as of June 1st. The list below shows the standing of the chapters as of September 1st, the gain in membership for July and August being included.

1. Chicago	11. Indianapolis	21. New Haven
2. Detroit	12. *Syracuse	22. Buffalo
3. Pittsburgh	13. *ROCKFORD	23. Schenectady
4. Philadelphia	14. *Worcester*	24. St. Louis
5. *Cleveland	15. Cincinnati	25. Toronto
6. *New York	16. WASHINGTON	26. South Bend
7. Hartford	17. *North West*	28. Bridgeport
8. Milwaukee	18. *Springfield*	27. Rochester
9. BOSTON	19. **Tri City*	
10. LEHIGH VALLEY	20. **Providence*	*=Tied

The following explanations will be of assistance. The chapters shown in capitals have advanced their position from that occupied on June 1st. Those shown in italics are not occupying as high a position as in the previous report. Those printed in regular type (i.e. Chicago) are occupying the same position as in the previous report.

The following comments are self-explanatory.

TO CHICAGO (1), and DETROIT (2).

Detroit showed a gain of 23 members during the time just passed and but 44 members separate this chapter from Chicago and first place. There are in the office at the present time 20 applications for membership whose dues have not yet been paid and consequently are not included in this list.

Detroit has a membership committee that is working very conscientiously and showing results. It is probable that Chicago will take warning and act accordingly.

TO PITTSBURGH (3), and PHILADELPHIA (4).

These two chapters are occupying the same position as on the last report, there being but 19 members separating Philadelphia from third position.

TO CLEVELAND (5), and NEW YORK (6).

New York showed a gain and is at the present time tied with Cleveland parts which couuld introduce complications. The greatest advantage in this

for fifth position but Cleveland is awarded the higher place because it occupied this position in the last report. With fall activities approaching for both of these chapters, it is possible that the next report will show a change.

TO HARTFORD (7), and MILWAUKEE (8).

Milwaukee next to Detroit showed the largest gain in membership for the time covered by this report. Its growth has been so rapid that at the present time it is but 7 members behind Hartford in 7th position. The new officers and Membership Committee of the Milwaukee Chapter will not be satisfied in holding a place in the second division but have set the first division as their goal.

TO BOSTON (9), LEHIGH VALLEY (10), INDIANAPOLIS (11), SYRACUSE (12), and ROCKFORD (13).

But 6 members separate Rockford in 13th position from Boston in 9th place. Lehigh Valley is but 1 behind Boston, Indianapolis but 2, while Syracuse and Rockford are tied for 12th place, the position being awarded Rockford because of priority. A little work on the part of the Membership Committee of these chapters would be conducive to wonderful results and give the chapter a higher standing.

TO WORCESTER (14), and CINCINNATI (15).

Cincinnati is occupying the same position as in the previous report while Worcester is occupying one position lower having been in position 13 in the former report. But 8 members separate these two chapters and there are other chapters in 16th, 17th and 18th that are within striking distance of this group.

TO WASHINGTON (16), NORTH WEST (17), SPRINGFIELD (18), TRI CITIES (19), PROVIDENCE (20), NEW HAVEN (21).

But 7 members separate New Haven in 21st position from Washington in 16th place. The Washington Chapter showed an advance from 20th to 16th position due to the members in the Baltimore Chapter being transferred to the Washington Chapter. Providence and Tri City are in a tie for 19th place, one preference being awarded to Tri City. All of the chapters in this group are very close together as far as the number of members are concerned and the next report undoubtedly will show a radical rearrangement.

TO BUFFALO (22), SCHENECTADY (23), and ST. LOUIS (24).

But 1 member separates Schenectady from Buffalo and but 4 members separate St. Louis from the leader in this group. Inasmuch as these chapters have just been holding their own during the past year, they are in line for a large increase in membership and with concentrated effort their positions are sure to be advanced.

TO TORONTO (25), SOUTH BEND (26), ROCHESTER (27) and BRIDGEPORT (28).

The positions of these chapters remain unchanged although they could easily, with a membership campaign, increase their number so that it would not be long before they would be occupying higher positions. These chapters are all located in cities capable of supporting larger chapters than they have at the present time.

CHICAGO CHAPTER

THE September meeting of the Chicago Chapter was held at the Chicago City Club on Friday the 29th at 8 o'clock. The subject for this meeting was entitled "Heat Treating in the Rockies" given by T. E. Barker of Denver. The Chicago Chapter had a very good turn out to welcome Mr. Barker with whom every member in Chicago was thoroughly acquainted, and who by his untiring efforts was responsible for the formation of the Chicago Chapter and also of the National Society. The welcome and reception that was given Mr. Barker was typical of the hospitality of the Chicagoans.

CINCINNATI CHAPTER

The Cincinnati Chapter held its first monthly meeting on September 2 in McMicken Hall, University of Cincinnati. The meeting was preceded by a "get-together" dinner which was served at 6:30 p. m. and at 8 o'clock some important business matters were transacted. Following this order of business an inspection of the testing laboratory of the University was conducted. Prof. Jenkins made some demonstration tests on material in equipment in his laboratory.

The Cincinnati Chapter has prepared an interesting program for the coming year which is to cover the following subjects: The Blast Furnace and Pig Iron for the Foundry; Metallurgical Furnaces & Fuels; Grading of Iron; Autogeneous Welding; Stainless Steel; Case Hardening; Inspection of Foundry; Automobile trip to the American Rolling Mills Company at Middletown, Ohio and the Annual Dinner and meeting of the Chapter.

From the list of subjects which was given in the program, Cincinnati should have a very instructive and profitable program for the ensuing year.

CLEVELAND CHAPTER

The first meeting of the Cleveland Chapter will be held on October 17 in Room K of the Cleveland Engineering Society Rooms. This meeting will be a business meeting including a report of the delegates to the Annual Convention.

DETROIT CHAPTER

The Detroit Chapter held its first meeting of the year on Monday evening, September 11 at 8 p. m. in the General Motors Building. Prof. J. F. Keller of Purdue University delivered a very interesting illustrated paper on "Why Steel Warps." As this subject has been of special interest to all engaged in the heat treatment of steel a very good turn out was the result of the announcement of this meeing. The discussion which followed Prof. Keller's paper was very interesting and brought out some very good points with reference to the warping of metals during or as a result of heat treatment.

The second meeting of the season was held at the Cass Technical High School on September 25 at which time, Mr. R. S. Archer of the Aluminum Company of America presented his very interesting paper

entitled "The Slip Interference Theory of Hardening." This paper brought out an interesting discussion and proved to be of intense interest to all those in attendance.

SOUTH BEND CHAPTER

The South Bend Chapter held its first monthly meeting September 12 at the Y. M. C. A. Following a short business meeting, Mr. V. A. Crosby presented a paper entitled "Manufacture of Gears" which brought forth a very interesting discussion which consumed fully one hour. Following this paper the delegates to the annual convention were appointed. They are as follows: Messrs. Al Johnson; J. A. Kingsbury and W. F. Newhouse.

ROCHESTER CHAPTER

The Rochester Chapter held its first meeting of the season 1922-23 on Monday evening, September 11th in the Rochester Engineering Society rooms. Mr. W. R. Shimer of the Bethlehem Steel Company presented an illustrated talk covering the "Manufacture of Steel." Mr. Shimer's paper proved to be highly interesting and instructive as shown by the discussion which followed. This talk was the first of the progressive meetings planned for this season dealing consecutively with Rolling, Forging, Carburizing, Tool Steels, Automobile Steels, Metallography, Pyrometry, Furnaces and Equipment.

ST. LOUIS CHAPTER

The St. Louis Chapter held its monthly meeting on Monday evening September 18th at the American Annex Hotel. The meeting was preceded by a "get-together" dinner served at 7 p. m. Mr. Francis B. Foley, Metallurgist, Bureau of Mines, Rolla, Missouri, presented a paper entitled "Annealing." Mr. Foley presented some very interesting thoughts on annealing and his paper developed considerable interesting discussion.

TRI CITY CHAPTER

The Tri City Chapter held its first meeting of the season on September 14th at the Davenport Chamber of Commerce. Mr. O. T. Muehlemeyer, Chief Metallurgist of the Barber-Colman Company of Rockford and Chairman of the Rockford Chapter, presented a paper entitled "Hardening Practice." As Mr. Muehlemeyer is an authority on heat treating his paper proved to be very instructive and brought forth some interesting discussion.

SPRINGFIELD CHAPTER

Springfield Chapter held its first meeting Friday evening, September 22nd in the Technical High School auditorium at which time a six-reel film entitled "Manufacture of Armco Iron" was presented. This picture was taken at the plant of the American Rolling Mills Company at Middletown, Ohio, and showed their manufacturing process from the ore to the finished product.

INDIANAPOLIS CHAPTER

The first meeting of the season of 1922-23 was held by the Indianapolis Chapter of the American Society for Steel Treating, in the di-

rectors' room of the Indianapolis Chamber of Commerce, on Monday September 11th.

A short business session was held during which the tentative program was outlined for the season following. It is the intention of the program committee to vary the program this year somewhat. Every other month Indianapolis Chapter is to have one of its members speak on the local industry which he represents. This is done in the endeavor to inform the other members as to the progress of the industry in our home plants. The other months will have out of town speakers who it is hoped can be induced to talk on the manufacture of steel, starting in the first month with iron ore and continuing every other month thru the many processes in the steel industry. Mr. J. Weaver Smith, Industrial Engineer of the Citizens Gas Co., of this city invited the Chapter to an inspection trip for its January meeting at the local gas plant to see the manufacture of coke ending up with a dinner given with the compliments of the Gas Company.

The meeting was then turned over to Mr. H. E. Haywood who by means of Lantern slides, conducted a very interesting tour thru the Link Belt Co., plant and explained the interesting points of design and manufacture of Silent Chain.

The meeting adjourned until the next meeting which is to be Oct. 9th.

LEHIGH VALLEY CHAPTER

The Lehigh Valley Chapter has announced its program for the coming year starting with their September meeting which is to be a "Get-together" picnic on the 9th.

In October there will be two meetings, one in Bethlehem, the subject being "Pyrometry" and the other being in Detroit—the International Steel Exposition and Conventions.

In November the meeting will be in Bethlehem in connection with the Lehigh Valley Engineering Society, the address being by a prominent engineer.

The December meeting will be in Easton with the subject of the meeting "History and Application of Chemistry to Local Industries."

In January the meeting will be in Bethlehem on the subject of "Metallography."

The February meeting will be in Easton and will be a dinner meeting and the paper will be "A Talk on the Steel Industry" by a prominent engineer.

In March the meeting will be held in Bethlehem at which time the "Heat Treatment of Tool Steel" will be discussed.

In April the meeting will be held at Reading and the paper for this meeting will be the "History of Eastern Pennsylvania Iron and Steel Industry."

In May the meeting will be held in Easton at which time moving pictures of Steel Manufacturing Operations and the annual business meeting will be held.

In June the meeting will be held in Bethlehem the 14th and 15th—Eastern Sectional Meeting of National Society.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

NEW MEMBERS

ARMITAGE, J. B., (M-7), 1084-39th St., Milwaukee, Wis.
BADGER, A. C., (M-9), 49 Parker St., Watertown, Mass.
BEACH, H. L., (M-9), 11 Hackfeld Rd., Worcester, Mass.
BENDER, C. P., (M-9), Studebaker Corp., South Bend, Ind.
BLOOD, B. H., (M-9), Pratt & Whitney Co., Hartford, Conn.
CHAMBERLAIN, V. V., (M-9), 722 Ave. H., Bethlehem, Pa.
CLARK, K. L., (A-6), 572 W. Randolph St., Chicago, Ill.
COLLINS, E. F., (M-9), 1926 Fullerton Ave., Detroit, Mich.
COLLINS, H. N., (M-9), Continental Motors Corp., Muskegon, Mich.
CRUICE, J. J., (A-8),1458 Lawrence Ave., Detroit, Mich.
DALRYMPLE, (M-9), 1407 Washington St., Easton, Pa.
DIETRICH, J. A., (M-9), 5656 Rogers St., Detroit, Mich.
DILLARD, J. B., (M-9), Cleveland Twist Drill Co., Cleveland, Ohio.
E. I. DUPONT de NEMOURS & CO., (Sb.-10), Wilmington, Del.
EHMAN, PRESTON, (Jr-9), 320-14th Ave., Newark, N. J.
GRIFFEN, R. J., (M-8), 2622 Lawndale Ave., Flint, Mich.
HAGLUND, P. E., (M-9), 223 Pasadena Ave., Highland Park, Mich.
HAYES, DR. ANSON, (M-9), 320 Stanton Ave., Ames, Iowa.
McELROY, L. T., (M-9), Standard Automatic Products Co., Corry, Pa.
McKEOUGH, J. J., (M-9), 8794 Quincy Ave., Detroit, Mich.
MURDEN, C. S., (M-6), 4916 N. Kedzie Ave., Chicago, Ill.
NICKEL, F. W., (M-9), Bowen Prod. Corp., Detroit, Mich.
REED, E. L., (M-9), 19 Westmoreland Ave., Arlington Heights, Mass.
ROYCE, F. E., (M-7), 1200 N. Main St., Detroit, Mich.
SMITH, F. W., (M-9), 518 Ave. "L," Bethlehem, Pa.
STEVENSON, G. I., (A-9), 2533 Broadway, Cleveland, Ohio.
STILWELL, E. W., (M-9), 480-9th St., Royal Oak, Mich.
STOLL, J. H., (Jr-9), 602 West Broad St., Bethlehem, Pa.
STUART, C. W., (M-7), 52 Garfield, Detroit, Mich.
SYLVESTER, N. J., (M-9), 345 Ave. "K," Bethlehem, Pa.
THOMAS, E. A., (M-8), 9771 Chenlot Ave., Detroit, Mich.
URSHEL, J. M., (M-10), Universal Machine Co., Bowling Green, Ohio.
WALTZ, W. H., (M-9), 227 W. Broad St., Bethlehem, Pa.
WARD, W. J., (M-10), 23 W. Congress St., Corry, Pa.
WELLS, F. O., (M-9), F. O. Wells Co., Greenfield, Mass.
WENK, E. O., (M-7), 1200 N. Main St., Ann Arbor, Mich.
WILLIAMS, C. C., (M-9), Bowen Products Corporation, Detroit, Mich.
ZUEGE, D. C., (M-8), Sivyer Steel Casting Co., Milwaukee, Wis.

CHANGES OF ADDRESS

ARTHUR, W., (M-12), from Reeds, Mo., to Texas Christian Univ., Fort Worth, Tex.
BECKER, M. E., from Winsor Ave. to 329 Church St., Hartford, Conn.
BENDLEY, W. P., (M-12), from 2384 E. Grand Blvd. to 544 Harper St., Detroit.
BORNSTEIN, H., (M-12), from 636-10th St. to C/o Deer & Co., Moline, Ill.
CARTER, H. G., from Florence Ave., Pittsburgh to 9038 Prospect St., Orange, Mass.
CHAMBERS, A. A., (M-5), from 225-32nd St. to 573 Superior St., Milwaukee, Wis.
GOODRICH, R. H., from L. M. Axle Co. to 1924 E. 105th St., Cleveland, Ohio.
GUISWITE, R. D., from Park Ave. to 2455½ N. Delaware St., Indianapolis, Ind.
LaFORE, P. J., (A-11), from West St. to 149 Tremont St., Boston, Mass.
MOREY, J. B., (M-2), from Crucible Steel Co., Dunkirk, to 127 Summit Ave., Buffalo, N. Y.
NILSON, H. T., from Ridgeway, Chicago to 1828 S. 48th Court, Cicero, Ill.
OSTERLUND, B., (M-4), from 4538 Wayne Ave. to 1733 W. Wingohocking St., Philadelphia.

PELOT, J H., from Dover, N. J., to 329 Park Ave., E. Orange, N. J.
REED, B. F., from Cramer St., Milwaukee, to 368-2nd Ave. Wauwatosa, Wis.
ROSEN, J., from Harms Hotel, Rock Island, Ill., to Rosen Machine Works, 126 Front St., Davenport, Iowa.
SMITH, L. A., from E. Market St. to Box 25, Scranton, Pa.
STEVENSON, F. L., (M-11), from Prospect Ave. to 2121 St. Clair Ave., Cleveland.
SWANBERG, C. G., (M-11), from Decatur, Ill. to 101 School, Geneva, Ill.
WIGGINS, C. R., from Flint, Mich. to 915 Eureka St., Lansing, Mich.
WILLIAMS, G. A., from E. 146th St., Cleveland to 20 Seymour St., Fredonia, N. Y.
WOODWARD, A. F., from E. 65th St. to 6205 Kinsman Rd., Cleveland, Ohio.
WYZALEK., J. F., (M-11), from Kearney, N. J., to 284 Argyle St., Arlington, N. J.
YEOMANS, L. I., from 1308 Monadnock Bldg. to 962 Monadnock Bldg., Chicago, Ill.

MAIL RETURNED

HARTMAN, FRED, N. E. Electric Company, Rochester, N. Y.
MILLER, C. C., 2427 Fourth St. N. E., Minneapolis, Minn.
MILLER, J. K., 531 Franklin St., E. Pittsburgh, Pa.
SMITH, J. R., 13 Washington St., Armor Park, Charleston, W. Va.
SPACE, J. H., Ludlum Steel Company, Philadelphia, Pa.

EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

Important Notice.

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITION WANTED

REPRESENTATIVE-SALESMAN. Eight years experience in selling steel products such as alloy and tool steels, bars, plates, shapes, axles, wheels and tires, and miscellaneous forgings. At present in charge of sales of forgings, wheels, tires, tool and alloy steels in the Pacific Coast Territory for large steel concern. Would like to correspond with steel company desiring a capable representative on the Pacific Coast. Address 10-1.

METALLURGIST or CHEMIST. Exceptionally good experience together with a record of absolute satisfaction. Available at once. Eastern location preferred. Address 10-5.

CHEMIST and HEAT TREATER. Technical graduate. Experience in chemical, physical testing and heat treating of steels. Eastern location preferred. Reasonable salary. Address 10-10.

WANTED by a practical man with 22 years' experience with some leading firms of the United States, position as Supervisor or foreman of Heat Treating. Address 8-5

ANALYTICAL CHEMIST thoroughly familiar with the analysis of steel and steel works materials. Write, stating age, experience and salary required. Address 10-15.

GRADUATE CHEMIST who has had several years' experience in metallurgical analysis, analysis of iron and steel, etc. His work will be for the present, at least, wholly analytical. Address 10-20.

YOUNG MAN with four years experience in the heat treatment of steel and who has taken a course in metallography, wishes a position with some concern where there is a chance for advancement. Best of references. Address 9-1.

UNUSUAL opportunity to secure exclusive sales agency for tool steel mill in Detroit and Los Angeles districts. Mill long established and products of proven quality. Would require experience in selling steel and moderate capital. Address 9-15.

POSITIONS OPEN

POSITION OPEN as Assistant Metallurgist with large plant making bearings. College graduate with some years practical experience in heat treating or steel mill work preferred. State in reply education, experience, and salary desired. Address 9-5.

WANTED—In tool and alloy steel research department 1921-1922 technical graduate who has specializvd in iron and steel metallurgy. Duties include running experimental melting furnaces, oil and electric; heating furnaces; and wide range of general work. Position offers good opportunity for future. Address 7-13.

Reviews of Recent Patents

1,427,121. Heat Treatment of Manganese Steel. Wesley G. Nichols, Chicago, Ill., assignor to American Manganese Steel Company, Chicago, Ill., a Corporation of Maine. Filed Sept. 18, 1920. Serial No. 411,250. 5 Claims. (Cl. 148-13)

1. An improvement in the art of heat treating manganese steel castings, which consists in subjecting such castings to heat, the maximum temperature of which never exceeds the critical temperature of such castings.

1,427,319. Apparatus for Annealing Thin Steel Sheets. Samuel Peacock, Wheeling, W. Va., assignor, by mesne assignments, to Wheeling Steel & Iron Co., Wheeling, W. Va., a corporation of West Virginia. Filed Nov. 9, 1920. Serial No. 422,814. 2 claims. (Cl. 148-16.)

1. Is an apparatus for annealing thin sheets of steel, the combination of a metal base plate, a mass of refractory non-heat conducting material carried by said base plate; means for supporting said steel sheets in packs on said mass; a heat insulating cover comprising a plurality of metal members spaced apart and provided with air spaces between them; enclosing said mass and packs of sheets; means to form an airtight joint between said base plate and said cover; means to exhaust the air from around said packs; and electric heating means for heating said packs to an annealing temperature, substantially as described.

1,427,390. Apparatus for Use in Annealing or Otherwise Treating Metals. Alfred Howgate, Keighle, England. Filed Feb. 25, 1920. Serial No. 361,172. 4 claims. (Cl. 266-5.)

1. In the annealing of metals, a pan for the reception of the articles to be treated, detachable framework supported by said pan, and refractory material supported by said detachable framework.

1,428,534. Steel and Iron Alloy. Philippe De Clameey, Boston, Mass., assignor to B. F. Sturtevant Company, Hyde Park, Mass., a corporation of Massachusetts. Filed Oct. 6. 1919. Serial No. 328,685. 2 claims. (Cl. 75-1.)

1. An alloy of iron or steel, containing over 1¼ per cent and less than 6 per cent of cobalt, over ½ per cent and less than 6 per cent of chromium, over ¾ per cent and less than 7½ per cent of nickel, and over ½ per cent and less than 3 per cent of silicon.

1,428,637. Yield-Point Detector. Morton C. Hutchinson, Woodbury, N. J., assignor of one-half to Leon G. Buckwalter, Merchantville, N. J. Filed Feb. 26, 1919. Serial No. 279,368. 10 claims. (Cl. 73-51.)

1. In a device of the character described a body portion, an arm carried thereby and provided with a point to engage the specimen to be tested, a second arm pivoted upon the body portion and having a point to engage the specimen, means to hold the device in place while in use, and circuit closing means operated by the pivoted arm.

TRANSACTIONS

of the

American Society for Steel Treating

Vol. III Cleveland, November 1922 No. 2

1922 CONVENTION

THERE is always a temptation to say that the most recent Convention of the Society is the best in the history of the craft, partly because each annual gathering of the American Society for Steel Treating brings so much of inspiration, so much of genuine pleasure and so much that is helpful, one is prone to forget the excellent conventions that have gone before.

The papers presented though fewer in number than at the previous Conventions were of a very high quality and over 50 per cent of them had been reprinted in the TRANSACTIONS. Consequently the discussion of these papers was more enlightening and instructive than the discussions at previous conventions. Appreciation of the entire membership goes out to those individuals who prepared papers for presentation at Detroit. There is no doubt that service to others through the Society, as well as in other ways, has its natural reaction and that he who serves grows in a fuller understanding of the things worth while and incidentally achieves worldly success.

The Exposition held in connection with the Convention was also a decided success. Manufacturers' representatives had been on the ground for several days prior to the official opening on Monday morning getting things in shape. There was no confusion when the show opened. Everything was ready and Monday proved a mighty good day for the exhibitors, because the visitors who had come in unusually large numbers could devote their undivided attention to the exhibits. Manufacturers had spared no expense to make a proper presentation of their products and it was generally voiced by all those in attendance that the manufacturers were to be complimented and commended for the excellency of their exhibits.

The members of the Detroit Chapter were busy every minute in taking proper care of the members and only the heartiest praise was to be heard on all sides for the success of the Detroit Convention and Exposition.

The Convention and Exposition have set a standard for the future to follow and it is needless to say that concentrated effort and hearty co-operation will be necessary in order that the American Society for Steel Treating may continue to increase its usefulness at its annual meetings.

RECOGNITION

THERE must be a beginning of all things yet it is seldom the privilege of any individual or any group of individuals to suitably award those who have planted the seeds from which a successful harvest has been reaped.

Nothing makes a more lasting impression than due regard for those who are accountable for a notable achievement, so that it must indeed have been a very propitious and happy occasion for the membership of this Society when upon authority of the Board of Directors, there was conferred upon Mr. Wm. P. Woodside and Mr. Theodore E. Barker, Founder Memberships in the American Society for Steel Treating. Those who are familar with the activities of the two gentlemen in the work of the organizations from which the present Society is the outgrowth are cognizant of the excellent work they did in laying a firm foundation upon which the present structure is erected. The Society in recognizing these two individuals, confers an honor upon itself and future time will tell more clearly than now, how well and important has been the work of these two capable men who have made for themselves a lasting niche in the Hall of Fame of Founders of technical societies.

A CONTEST

AT the Delegates' meeting in Detroit, a resolution was proposed and favorably acted upon that the Board of Directors of the A. S. S. T. should be requested to inaugurate a membership contest among the various chapters and offer suitable prizes to the chapters showing the largest increase in membership during a certain period. The Board of Directors took the matter under consideration and appointed a committee to investigate. This special committee reported at the regular meeting in Cleveland on October 27. This committee was moved by the thoughts expressed by many members of the Society that mere increase in membership should not be the sole aim of the organization. It is believed rather that the continued interest of a stable membership with a sound and healthy growth would best promote the aims of the Society.

It therefore recommended that combination prizes be given to the local chapters for percentage of net increase in membership and percentage attendance of members at the meetings of local chapters. It was the committee's idea that one was quite as important as the other, and for that reason each should count 50 per cent toward the prizes.

At the delegates' session the sum of $300.00 was suggested as the amount to be devoted to prizes, but the delegates did not have in mind the questions of attendance. The committee thought that inasmuch as more energy would be required to conduct the combination campaign than would be necessary if only the question of increase in membership were invloved, the prizes should be made larger. For that reason the committee recommended total prizes of $500.00.

The action of this committee and the Board of Directors in arranging this contest so that one of its purposes will be the establishment of a stable membership and a sound and healthy growth of the Society will undoubtedly receive the hearty approval of the entire membership. The rules of the contest are published under Chapter News of this issue of the TRANSACTIONS.

GENERAL CHAIRMAN LETTER

To The Members of the Detroit Committees

Fourth Annual Convention, 1922.

Gentlemen:—

I desire to express my appreciation and sincere thanks to the chairmen and members of the various committees who worked with me during the preparation and time of the Convention and Exhibition of our Society.

I should like to write each one of you a personal letter but in place of that, I am taking this opportunity to publicly express my thanks so that all members of the Society will be cognizant of your work as well as my appreciation.

My thanks to:

Mr. C. N. Dawe and the members of the Meetings and Papers Committee for the excellent program prepared for the technical sessions as well as the efficient arrangements of the meetings rooms.

Mr. C. T. Bragg and the members of the Finance Committee for their valuable work in raising the money necessary for conducting the activities of the week;

Mr. W. B. Hurley and the members of the Transportation Committee for the excellent manner in which this part of the Convention was taken care of;

Mr. Jack Dailey and the members of the Exhibition Committee for the valuable assistance and services rendered to the National Secretary and to exhibitors;

Mr. F. Walter Guibert and the members of the Publicity Committee for the excellent publicity given the events of the week;

Mr. Arthur Schaffer and the members of the Hotel Committee for their successful efforts in finding accommodations for all of our members and guests;

Mr. W. J. Learmouth and the members of the Ladies Committee for performing a pleasant duty in a most acceptable manner.

Mr. Frank G. Davis and the members of the Entertainment Committee appreciation for excellent services well done in providing entertainment for exhibitors and guests. Detroit regrets exceedingly that Mr. Davis has been transferred to take charge of the Buffalo Territory for the Atlas Steel Corporation and sincerely hopes that the reason for his leaving Detroit was not resultant upon his connection with the Entertainment Committee. In all events we thank him for his capable assistance and wish him well.

My thanks are also due to the Chairman of all committees in that they managed their departments so well that they all kept within the budget allowed them.

Yours very truly,

W. P. Woodside,
General Chairman,
Detroit Convention Committees.

WHAT THE TRADE PUBLICATIONS SAY

Iron Age

IN A ten-page review of the activities at the International Steel Exposition and Convention of the American Society for Steel Treating, the Drop Forging Institute and the Drop Forgers Supply association, the *Iron Age* of Oct. 12 says in part:—

"An unqualified success was the general verdict of those who attended the fourth annual convention and exhibition of the American Society for Steel Treating last week at Detroit, Oct. 2 to 7. The record made there by this society, only three years old, both in technical papers and in exhibits, insures it a place among the leading technical organizations in the country and stamps its annual meeting as one to be looked forward to and to be reckoned with. Both the convention and the exhibition, called this time an 'international steel exposition,' exceeded in scope and attendance the three previous affairs at Chicago, Philadelphia and Indianapolis in 1919, 1920 and 1921, respectively. The registered attendance of members only was about 1300 of a total membership of a little over 3000. This is the first year that only membership attendance was recorded. An official estimate of those participating in all activities is 18,000 against 8000 to 9000 last year.

"Uniting with the steel treaters was the first annual convention of the American Drop Forging Institute with which was also associated the Drop Forge Supply association. Their registered attendance exceeded that of the recent meetings of the American Drop Forge association, the older and parent organization.

"The fourth floor of the spacious building of the General Motors Corporation afforded an ideal place for the technical sessions and the exposition, the former being held in close proximity to the latter. As for the city itself, Detroit probably contains in its automobile industries more extensive industrial applications of heat treatment than any other American city.

"The exhibition of heat-treating equipment and processes of heat-treated material by large steel companies and other allied interests was imposing in its scope and impressive in its presentation. In floor space and in material exhibited, it exceeded any previous exhibition. The entire affair occupied about 55,000 square feet of floor space taken by about 100 exhibitors; in Philadelphia in 1920 there were 125 exhibitors but less floor space. Not only the number of steel companies represented but the new equipment and other matters presented were features.

"The exhibits of forging machinery, machine tools and accessory equipment, while not large in numbers, were a noteworthy center of attraction and several machines are said to have been sold.

"The technical sessions of the steel treaters were not only well attended in most cases but, as contrasted with the Indianapolis meeting last year, there were fewer papers and almost no simultaneous sessions. As against nearly 75 papers scheduled on the program last year, this year the various sessions covered 20 to 25 papers, including several symposiums. The sessions were devoted to carburizing, heat-treating problems, tool steel, aircraft failures, with three practical round table discussions on heat treating and three symposiums on metallurgical education, on hardness testing and on research. Most of the papers were available in printed form, a commendable departure from previous con-

ventions. The society's journal, TRANSACTIONS, containing many of them, was distributed.

"Plant visitations were numerous and largely taken advantage of; they included both the Highland Park and River Rouge plants of the Ford Motor Co. and the plants of other large companies.

"A new feature was the holding of regular sessions in Detroit of some of the committees and subcommittees of the American Society for Testing Materials."

Iron Trade Review

The *Iron Trade Review* of Oct. 12 in a seven-page review of the International Steel Exposition and Convention, makes the following comments

"Probably the widest representation of the iron and steel industry ever witnessed in this country was assembled at the fourth annual convention and exhibition of the American Society for Steel Treating at the new General Motors building, Detroit, Oct. 2-6. At the invitation of this society the American Drop Forging institute and the Drop Forge Supply association held simultaneous and joint meetings with it during the week. Approximately 1300 members of the steel treating society and 150 members of the forging associations were registered while more than 18,000 people attended the exhibition, which was the most complete conducted by the society. About 100 manufacturers of steel, heat treating equipment and materials, machinery and forge products were represented with exhibits. While the success of this year's meeting was assured largely by the continuous growth of the society, the fact that Detroit, one of the country's leading centers for the heat treating and forging industries, was selected as the meeting place added to the interest.

"Features of the program were discussions of practical heat treating problems, sessions on research, employment, metallurgical investigations, production and costs and forging practice. On Thursday a bronze tablet was dedicated to the builders of the first bessemer converter in America. Social functions included a smoker, dance and banquet participated in by the three organizations. Inspection trips to various Detroit manufacturing plants proved to be of interest to many members."

Chemical and Metallurgical Engineering

Chemical and Metallurgical Engineering in its Oct. 11 issue devoted four pages to a review of the exposition and convention. A part of this review is as follows:—

"Steel treaters have done something which is perhaps unparalleled in the history of American technical societies—they have held a national convention at which 40 per cent of their entire membership enrolled was present. Being held in Detroit, several of the larger local chapters in the Middle West came in a body, but in order to set that record a great many others traveled from New England and the coast states.

"They were rewarded by the best meeting and exposition the American Society for Steel Treating has ever had. Being but a young organ-

ization, the earlier conventions showed many marks of inexperience on the part of their managers. Much praise is therefore due to the Detroit committees, under the general chairmanship of W. P. Woodside, for their part of the work. They provided quite adequate meeting and exhibition facilities in the magnificent General Motors Office building, gathered together a notable list of meritorious technical papers, and provided a number of excursions into manufacturing plants and social entertainments which filled every minute. No doubt some of the successful results—particularly in the exposition of steel and steel-treating equipment—were due to the co-operation of the Amerian Drop Forging Institute, which held its annual convention in conjunction with the Steel Treaters as a sort of co-operative affair.

"One feature of the non-technical activities is worthy of comment and emulation. It seems that the first bessemer steel made in America on a commercial scale was blown in 1864 by William Kelly at the village of Wyandotte, on the river a few miles south of Detroit. The site of these works—now long since dismantled—is the business center of the present community, but is now marked by a bronze tablet erected by the Detroit members of the Society for Steel Treating.

"Kelly, it may be recalled, was an ironmaster who had discovered the pneumatic process many years before when observing the action of the air blast on the metal in one of his forges, left unprotected by the usual charcoal blanket. In fact, he had made knobbed iron with little or no charcoal for many years before he was able to interest anyone sufficiently to finance large experiments on what is now known as the bessemer process. A plant was finally erected alongside the blast furnaces of the Wyandotte Iron Works, and operated with the usual vicissitudes of radically new processes for several months. A considerable tonnage of steel, however, was made, rolled and sold. During part of that time Captain Robert W. Hunt was in charge of the operations, and fortunately this venerable engineer was able to be present at the dedication ceremonies and give some reminiscences of those early times.

"An echo of the vicious litigation which was fought over the Kelly American patents, the bessemer British patent and the improvements made by Mushet was heard in the remarks made by William C. Kelly, the son of the discoverer of the pneumatic process. It seems that Kelly's achievements in the manufacture of iron without charcoal had become fairly well known, both here and abroad, through information spread by Kelly's Cincinnati house—jobbers and importers of iron and steel. During these times the forges were visited by two Englishmen of intelligence, who remained a few months, even assisting the owner in his experiments looking toward an improvement of the process or an adaptation to larger-scale operation, eventually leaving as suddenly as they appeared. According to the son, William C. Kelly, one of these visitors was identified by his father as Bessemer, when a photograph of the latter was brought over from England shortly after the introduction abroad of Bessemer's process in a commercial way. This incident, mentioned by William C. Kelly as never before having been made public, was told him by his mother before her death, several years ago."

American Machinist

The *American Machinist* of Oct. 12 makes the following remarks in review of the fourth annual convention and exhibition:—

"The convention of the American Society for Steel Treating held in conjunction with the annual meeting of the American Drop Forging Institute which was brought to a close last week in Detroit was regarded by all present to have been the most successful in the history of both bodies.

"The total attendance upon the convention was estimated at between eighteen and twenty thousand persons. Of the membership in both bodies, there were thirteen hundred present or approximately 50 per cent of the total.

"The chief feature of the convention was the number of executives present and interest was centered chiefly in the exhibit which was considered to be the most successful ever held, fully one hundred more companies displaying their products than in previous years. Nearly all the machinery displayed on the floor was sold during the convention.

"Tuesday and Wednesday evenings, Oct. 3 and 4 were given up to smoker and carnival frolic. On Thursday, Oct. 5 the annual banquet was held at which the chief speakers were: President Burton, University of Michigan and Frank Hook Alfred, president of the Pere Marquette railway. T. E. Barker and W. P. Woodside, both of whom have been instrumental in establishing and furthering the interests of the American Society for Steel Treating were the recipients of founder memberships in recognition of their work.

"On Thursday afternoon a bronze tablet was unveiled at Wyandotte, Mich., to William Kelly who was the first to use the Bessemer process in America.

"Among the papers read during the sessions of the convention were the following: Furnace Atmospheres and their Relation to the Formation of Scale by G. C. McCormick: The Effect of Structure Upon the Machining of Tool Steel by J. V. Emmons; Case Hardening by A. H. d' Arcambal; Lathe Breakdown Tests of Some Modern High Speed Tool Steels by H. J. French and Jerome Strauss; Heat Treating in Lead by R. B. Schenck; Irregularities in Case Hardened Work caused by Improperly Made Steel by E. W. Ehn; Study of Some Failures in Aircraft and Engine Parts by J. B. Johnson and Samuel Daniels; and Carburizing and Decarburizing in Case Hardening by H. B. Knowlton."

Western Machinery World

The *Western Machinery World* in its October issue devoted two pages pages in reviewing the International Steel exposition and convention of the American Society for Steel Treating. In part it comments as follows:—

"This convention, held Oct. 2 to 7 at Detroit, has brought out a number of very excellent papers on various technical phases of heat treatment, carburization, case hardening, and metallographical research in steel and ferrous alloys. For the convenience of our readers we are here reprinting through the courtesy of the TRANSACTIONS of the American Society of Steel Treating, abstracts of these papers. *Undoubtedly the* TRANSACTIONS *of this society constitute the best readily available literature on the up-to-date experience of America's foremost experts in steel treating.*"

THE FOURTH ANNUAL EXPOSITION AND CONVENTION A DECIDED SUCCESS

MODESTY forbids that we sing too highly our own praises—our own praises in respect to our fourth annual convention and exhibition—The International Steel Exposition. This convention beyond all fear of contradiction was an unqualified success. From the pleasant words of commendation and encouragement expressed by many of the leading trade publications we feel that we can be just a little bit proud of the results of our efforts. These efforts were not confined alone to any one individual or group of individuals but was the culmination of the efforts of our entire membership. The members of the Detroit Chapter are to be congratulated upon the very successful manner in which the exposition was handled. They provided an excellent exhibition on the fourth floor of the wonderful General Motors Building and likewise provided a very interesting and meritorious program of technical papers, plant visitation and social entertainment.

The American Drop Forging Institute and the Drop Forgers Supply association who held their convention simultaneously with the American Society for Steel Treating, likewise provided a very interesting convention program and in no small way assisted in making the International Steel exposition and conventions a profound success.

The number of exhibitors was larger this year than ever before and the variety of exhibits was greater than at any of the previous annual expositions. The exhibition hall comprising more than 50,000 square feet of floor space was admirably adapted to our needs and more than 20,000 persons visited the show throughout the week.

As one of the technical papers comments, the American Society for Steel Treating has accomplished something that no other technical society has up to the present time. Out of a total membership of a little more than 3000 members, 1300 were registered as in attendance at this convention. This record has been unprecedented. Perhaps the fact that the fourth convention was held in Detroit, the automotive center, vitally interested in the heat treatment of metals, served as an added incentive for our members and guests to attend the convention and likewise avail themselves of the opportunity of seeing how they do it in the Auto City. Undoubtedly all of these factors had their direct bearing on the success of our show.

For those who were unable to be in attendance an outline of the week's activities may be interesting.

Monday morning at 11:00 o'clock the doors of the exhibition were thrown open. Fully an hour previous several hundred members had registered. From Monday morning throughout the week a steady registration of members was made.

At 2:00 o'clock the opening session of the society was held in the large meeting room adjoining the exhibition hall. The meeting was called to order by L. A. Danse, who gave the following address of welcome to the visiting members and guests.

"I want to express a few thoughts on behalf of the Detroit Chapter. It has been a very real pleasure to us to do the work that we have been doing the last few months. It has taken a great deal of time and

considerable energy, but I don't think that we could have spent too much for the fellows who are coming. We feel that you are pretty much the backbone of the industry. If you fall down, the machine shop can't do a thing. I am pretty much reminded of a remark that I heard Stewart Edward White make at a gathering in Los Angeles. He was a little afflicted with stage fright; he got up and looked at the crowd and said, 'Well, fellows, I am tickled pink to see you, here is Mr. Crossman, he will talk to you.' That is about the way I feel. We have a speaker who can talk. He is going to give you a real hospitable welcome to Detroit. That is beyond my bounds. I am a good deal like my wife's uncle was, one time when we went to visit him. He felt all the hospitality in the world and wanted to make us feel at ease. He was a rough country chap, rather unschooled. His wife tried to coach him a little, and when we went in to sit down to dinner he said. 'Well, folks, I am home, and I wish you were too.' Well, we don't wish you were at home. We want you to feel at home. We had hoped that we would have a grand attendance. From the looks of things it is going to be bigger than we thought. The boys in the Detroit Chapter each one and collectively wish to welcome you, through me. Mr. Bragg has been deputized by Mayor Couzens, who was unavoidably prevented from coming, and Mr. Bragg will present to you the respects of our city's chief executive." (Applause).

Mr. Bragg: "Mr. Chairman and gentlemen, I am afraid I make a rather poor substitute for the Mayor, and yet a rather fortunate one, too, in a way, because I am interested in his administration as one of his commissioners.

"The Detroit Chapter has done a lot of very hard work, and no one appreciates it more than the Mayor. The Mayor told me yesterday that he had decided to attend your banquet on Thursday night,—and if you would excuse him this afternoon he would surely come to the banquet. He doesn't go very many places, but where he does go you may be sure he is taking a keen interest, and he will be there on Thursday night. The Mayor has made during his administration something of a record. However, he has to a certain extent retired from his politicial career and is more or less based on the steel business himself, so he is interested in everything that you do.

"We are saying to you that we are glad to have you come to Detroit. This is quite a convention city, and we have a lot of things here for you to see. I know, that about this time a year ago I was concerned with a certain convention, and we met to take up the plant visitation proposition, much as you have outlined in your program at this meeting. We soon discovered the problem was not where to go, but where not to go, or where to stay away from; there are so many big industries in Detroit it would keep a fellow busy if he spent all of his time in going around.

"I will say once more to you that the Mayor is particularly interested in the success of the convention and he would have been here personally today were that not absolutely impossible. I know you are going to have a long, hard program to go through during the week of the convention, and all of you should attend these meetings and if you do, you are going to hear about all the talking and about all the pape-

Courtesy *Iron Trade Review*

VIEW OF MAIN EXHIBITION HALL, INTERNATIONAL STEEL EXPOSITION, GENERAL MOTORS BUILDING, DETROIT

reading that you want to for a week or more. I will conclude with this and say to you once more that the Mayor will be with you on Thursday night." (Applause).

Chairman Danse: "Gentlemen, short and snappy seems to be the rule. I don't know what Mr. Gilligan is going to say, but if I am any judge, from past experiences, Mr. Gilligan is going to beat Mr. Bragg." (Applause).

President Gilligan: "Members of the Detroit Chapter, guests, and Mr. Bragg, it gives me great pleasure to thank the representative of the Mayor and the Detroit Chapter for their cordial welcome to this city. It is particularly appropriate that the American Society for Steel Treating should hold this convention in Detroit, because the Society really had its birth in this city, and the industry that made Detroit famous has really raised the heat treating game from a job to a profession.

"We have been to various chapters in the last three or four years with our convention. Each one has been a little bit better than its predecessor, each chapter has worked hard, and from the indications we see here today, Detroit is going to maintain that record.

"I am sorry that our 'Granddaddy,' Mr. Woodside, is not with us, for a few remarks just now. The attendance is going to be exceedingly large, however, because Detroit is not alone attractive as the home of the Steel Treating Society, but also for the varied industries here, and I am pleased to accept the cordial welcome to Detroit." (Applause).

Chairman Danse: "Mr. President and Gentlemen, I think the next item on our program is a thing which will interest Mr. Gilligan and Mr. Lynch more than anybody else. I don't know what kind of an expression I will see on Mr. Gilligan's face, he doesn't want to look at me right now. We are due to hear the report of the Tellers of Election." Mr. Simpson read this report which is as follows:

For President—one year—T. D. Lynch
For 2nd Vice President—two years—W. S. Bidle
For Secretary—two years—W. H. Eisenman
For Director—two years—S. M. Havens

Chairman Danse: "Congratulations to you, President Gilligan, on your past very successful year, and to you, Mr. Lynch. We are going to give you all the co-operation we possibly can the coming year.

You have heard the report of the Tellers. Its acceptance is in order." The report was then accepted by vote.

"It is now in order to introduce your newly-elected officers. (Introduces them). Now I am going to ask Mr. Lynch to take the chair and make a few remarks, and he will call for the reports of the National Secretary and the National Treasurer." (Applause).

President-Elect Lynch: "Mr. President, fellow members of the American Society for Steel Treating, it is a great pleasure for me to be at this convention and to be the recipient of this honor, but the acceptance of an honor of this sort carries with it a responsibility that I, as your president-elect, can only hope to make a success of through your co-operation, by the co-operation of our National officers, by the co-operation of each and every chapter, and by the further co-operation of each individual member. It is only through work of that sort that we can hope to succeed, as an organization, as we have succeeded in

the past. The details of the work for the coming year will have to develop after we have had a meeting of our board of directors. None of us can tell just what is going to transpire or just what our ideas may be, but in general we certainly have no idea of making any radical changes, of proposing anything radical other than that that was given to us by our fathers and carried on and executed by our predecessors. We feel that they have started well, they have built up an organization worth while, and through those same channels and through that same plan of working I see no reason why we should not prosper.

"There are a few things that are very important in an organization of this kind. Among them is the question of the committee work. I feel that the majority of the work of this Society that is permanent must be done through committee work, and some of those committees, to my mind, should be, perhaps, a little more permanent than they are today, such as the Technical committees, the Standards committee particularly, and the Research committee. Those two committees have work under way that cannot be accomplished in a year or two years. They must plan, they must plan for the future, and in doing that it is my thought that those committees perhaps should be increased in number from perhaps say three to five, and say in addition, to having the member hold office for a term of at least five years, and instead of the president of the Society appointing the chairman of these committees, I would like to see the committee elect their own chairman from amongst their own number, and each year elect new men. These are thoughts that I will lay before the board of directors later on, but is something that will not require the action of this body at this time. However, those are thoughts that it seems to me would be worth while acting on.

"Then in the appointment of the committees, I think perhaps in order to stimulate the committees and the chapters all over the country that the member of the Standards Committee should be the chairman of the Standards Committee of the local chapter which they represent. I think that would tie up the local chapters with the national body more closely, and I think in doing that it would help all of us.

"Now our motto, as suggested by our secretary last year, was *Service*: I think it is a good motto. Not the ability we have, but the ability we show, by Service, will measure our success for the coming year. We cannot lie down and dream ourselves into a success, but we must hammer and forge our way forward. We cannot make a success of treating poor material. Let us see that our material is right and that it is treated right. Don't sit down and take what comes; go after what you want. The best prize that this Society has to offer is the chance to work, to work hard, and to work for a purpose and a work well done. I think, if we will follow these ideas it will give you some idea of what my ideas are of our future work, and I wish to thank you." (Applause).

President-Elect Lynch: The next speaker on our list is Secretary Eisenman who will give his annual report.

Secretary Eisenman:

The Secretary is pleased to submit this report of the past year. It shows that your Society has been able to extend its service in spite of the fact that we have passed through a year of general depression.

The membership activities show a gain for the year as is evidenced by chart No. 1 which shows that 543 new members were enrolled in the Society, an average gain of 43 members per month. The largest gain of any one month occurred in June when 107 new members were received. This high peak was reached during a membership campaign by the Chicago Chapter.

We regret that all of the 543 members may not be added to the permanent rolls of the Society because during the months of January, February, March and April, 1922, the number of resignations received was at a very heavy rate

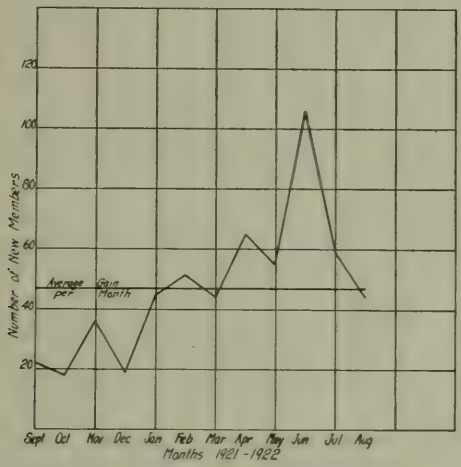


Chart 1. Showing Gain in Membership

inasmuch as many of the members whose dues expired during these months were out of employment and consequently did not feel inclined to continue the expenditure. During the year there were 398 resignations leaving a net gain for the year of 145 members. We feel confident however, that many of the members who permitted their dues to lapse will again take up active work in the Society and our records at the present show that many of these are being reinstated.

The ruling by the Board of Directors whereby the local chapter receives a larger percentage of the dues received from sustaining memberships has contributed materially to increasing activity in this class of membership and has in this way been of great financial assistance to the local chapter.

The Society has not yet made an impression on the field of possible members or its potential usefulness and there is every reason to believe that the coming year, with business conditions so much better the membership line will show a gradual increase from month to month, and we will close the year with a fewer number of resignations and a larger total of members.

As stated in the annual report of President Gilligan, the TRANSACTIONS has made commendable progress during the past year. The TRANSACTIONS this year contained 1238 pages of editorial matter, as compared with 840 pages published in Volume I. This is a net increase of 398 pages or about 47 per cent. An increase in the number of pages does not always indicate an increase in value to the members, however we are strong in the belief, judging from the many commendable letters that we have received from home and abroad, that the TRANSACTIONS is and will continue to be the leading publication on the heat treatment of steel.

Special commendation should be given to the Publication Committee in-

asmuch as they have given very largely of their time in reviewing papers and have been of very great assistance to the editor. We should not be unmindful of the firms using the pages of the TRANSACTIONS as an advertising medium. Many advertisers continued in the TRANSACTIONS even after they

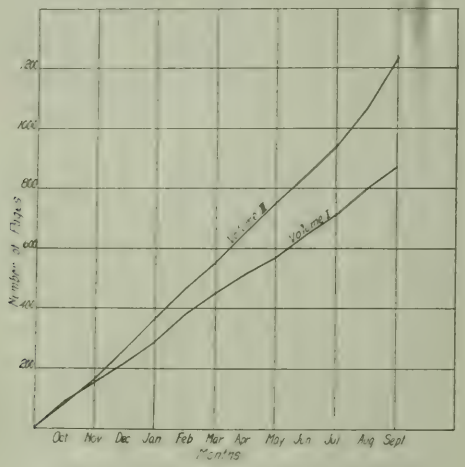


Chart 2. Showing Increase in Pages in TRANSACTIONS

had withdrawn from other publications. This support and co-operation from them is greatly appreciated by our entire membership.

About 150 members availed themselves of the opportunity to have their TRANSACTIONS bound at cost, by the National office, and the same plan will be continued with Volume 2.

Your Society sustained serious loss during the past year of one of our Honorary Members, Henry Marion Howe, and in commemoration of the exceptional achievement of Dr. Howe, the Board of Directors decided to set aside a fund of the Society in order to establish a medal to be known

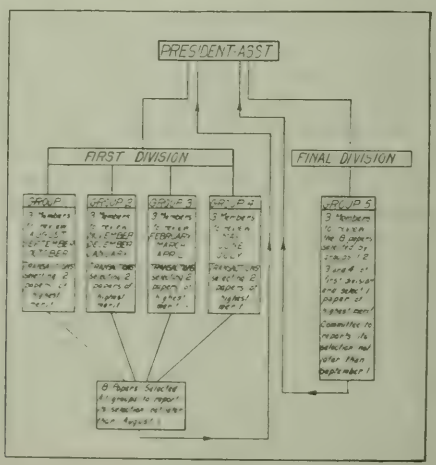


Chart 3. Showing Method To Be Used in Selecting the Howe Medal Winner

as the Henry Marion Howe Medal. The rules governing the award are as follows:

(1) The Board of Directors of the American Society for Steel Treating has established a fund to be known as the Henry Marion Howe Medal Fund, the proceeds of which shall be used annually to award a gold medal to be known as the Henry Marion Howe Medal.

(2) This medal shall be awarded to the author of the paper which shall be judged to be of the highest merit. All papers in order to be considered must be published originally in the TRANSACTIONS of the Society during the twelve months ending August 1st of the year in which the medal is awarded.

(3) The competition for the Henry Marion Howe Medal shall be open to all.

(4) The award shall be made by the Board of Directors.

(5) The award may be withheld at the discretion of the Board of Directors.

The rules governing the selection of the Committees on Awarding the Henry Marion Howe Medal are as follows and are graphically illustrated in Chart No. 3.

(1) There shall be appointed by the President, not later than June 1st of the year in which the medal is to be awarded, a committee on awards consisting of two divisions, the first of which shall consist of 12 members, divided into four groups of three each, each group being located in adjacent territory to facilitate meeting.

(2) Each group shall be assigned three monthly issues of the TRANSACTIONS and it shall be the duty of each individual of each group to read carefully all of the papers published in the three assigned issues and to select the two papers which are, in his judgment, of the highest merit.

(3) When each of the members of a group has made his selection, a meeting of all three shall be held and they shall select the two papers which, in the opinion of the majority, are of highest merit.

(4) Each of the four groups having reached its decision in a similar manner, four sets of two papers each will have been selected for final review.

(5) Each group committee shall report the papers selected by it to the President as soon as a decision is reached, but in any case not later than August 1st of the year in which the medal is to be awarded.

(6) The second division of the committee shall consist of three individuals to whom shall be assigned the eight papers selected by the four group committees.

(7) The second division of the committee shall decide which of the eight papers submitted to it is of highest merit, completing its work before September 1st, and sending its decision to the National President so that announcement and presentation of the Henry Marion Howe Medal may be made during the annual meeting.

President-Elect Lynch: "Gentlemen, the next item on the program will be shifted slightly, and we will have the announcement of the winners of the gold and silver medals for the best papers presented at the Indianapolis convention, by our Vice President, Mr. Allen."

Vice President Allen: "Prior to the Indianapolis convention it was announced that a gold medal and a silver medal would be given to those who had presented the two best papers during the year. Following the convention all the papers presented were read by the publication com-

mittee, and some 24 were set aside for further consideration. President Gilligan then appointed a committee consisting of Prof. C. H. Mathewson of Yale University, Mr. G. R. Brophy of the Research Laboratory of the General Electric company, and the speaker. Each of the members of that committee read all of the 24 papers, and then we had a meeting in Springfield at which the final selections were made. It was no easy matter, however, to select the two papers, because there were so many of such a high order of merit that it was only after much consideration and discussion that we arrived at a decision on the two.

"Your committee, having carefully read the papers submitted for our consideration, believe the gold medal should be awarded to Mr. E. J. Janitzky for his paper entitled 'A Contribution to the Problem of the Influence of Mass in Heat Treatment,' which, although it may indeed leave this broad subject open for further consideration, constitutes a bold and forceful attempt to express the effects of heat treatment in terms of mass and volume of the object treated.

"The committee believes that the silver medal should be awarded to Messrs. J. P. Gill and L. D. Bowman for their thoughtful and comprehensive paper on the 'Metallography of High Speed Steel.'

Mr. Janitzky: "Gentlemen, I thank you for the honor that has been bestowed on me. I would say that it is a big field for research work. Really all the experimental work that has ever been carried on in this field has never been given consideration, but, on the contrary, has been laid aside and pigeon-holed and forgotten. There is really a wonderful lot of data that has been written that could be put within the reach of everybody and which could be explained and used in the practical shop. It is a big field, and there is plenty of it to work on, and I hope there will be many such subjects that will be worked on in the same way. Thank you." (Applause).

Chairman Lynch: "Gentlemen, we will now hear the report of our treasurer for the past year, Mr. Emmons." (Applause).

Treasurer Emmons: "Mr. President and Gentlemen, I had hoped to show by means of lantern slides the curves which would show completely the exact financial status of the Society. Unfortunately, the electricity hasn't yet been turned on, and I will have to give verbally, as well as I can, the report.

In reporting briefly the status of the financial affairs of the Society, it seems first advisable to call attention to certain policies which have been inaugurated during the past year.

First, it has been found that the most suitable time for closing the books of the Society was December 31st. The fiscal year of the Society was accordingly established as January 1st, to December 31st, inclusive.

The policy of publishing an annual financial statement and balance sheet was anaugurated and the first certified financial statement of the Society was published in the May TRANSACTIONS covering the year of 1921.

A system of controlling the Society's finances by means of a budget has been worked out by the Finance Committee and is now undergoing its first year's trial.

The budget expected receipts for the year of $65,525.00 and expenditures of $62,316.00.

For the eight months ending August 31st, the total receipts exclusive of convention were excepted to be $35,505.00. The actual receipts were $31,-

078.00, being a shrinkage of $4,427.00, or 12 per cent. This shrinkage in the expected receipts necessitated a corresponding curtailment of our expenditures.

The expected expenditures exclusive of convention for the past eight months were $32,536.00. The actual expenditures have been $29,237.00, a shrinkage of $3,299.00, or 10 per cent. It is thus evident that our expenditures have been kept within a working margin of our income.

For the months of July and August, our income has been again exceeding our expenditures and our surplus has regained some of its losses during the earlier months of the year. This improvement has been largely because of increased receipts from dues.

Upon August 31st, the surplus of the Society above all liabilities and necessary reserves was shown by the books to be $7,444.20. Of this surplus $3,718.26 was in accounts receivable, $1,432.37 in office furniture and fixtures and $2,293.57 in working cash.

As soon as possible after the close of the fiscal year, a complete financial statement for the year 1922 will be published in the TRANSACTIONS.

President-Elect Lynch: "We have saved the best until the last, and we will now hear from our president, Mr. Gilligan."

President Gilligan: "I am glad to hear the treasurer's favorable report because not alone the directors, but the finance committee, consisting of Mr. Emmons and Mr. Campbell, and Mr. Herron, and Mr. Bidle met frequently and long and endeavored to provide a means of conveying to each member all the facts and a clear exposition of the financial progress of this society.

"I want to comment on some of the phases of Mr. Emmon's report, but I will hold those back until I arrive at the opportune time. Owing to the press of other work, I had difficulty in getting my annual report together, so I followed the advice of one chap who had prepared a technical paper for presentation before the A. S. T. M. he decided to pattern it after the modern skirt, 'long enough to cover the subject but short enough to be interesting.' (Laughter).

"Custom decrees that the retiring president shall render a statement covering the most important activities in the life of the society during the year then ending, much as the members of a commercial corporation demand from the officers a statement of the year's transactions in order that they may judge whether they are sailing or drifting.

"Because of various reasons which have little relation to the real principles of steel treating, a new style has arisen in late years in the rendering of some annual reports—known as the sandwich style. The first layer of the sandwich outlines the unusual and extremely depressing state of the health of the world in general, the meat layer carries the disagreeable news, and the final layer consists of a fervent prayer for the future, accompanied sometimes by a request for a contribution. Those who have considered at all the reports just rendered by our treasurer and our secretary will agree that the sandwich in this instance is not a disagreeable one.

"Notwithstanding the disturbed mental balance of the world in general, and of the unstable industrial conditions that have prevailed in our country in particular, our society shows in no uncertain manner

Courtesy *Iron Trade Review*

VIEW OF MAIN EXHIBITION HALL, INTERNATIONAL STEEL EXPOSITION, GENERAL MOTORS BUILDING, DETROIT

that it has been sailing and not drifting. Your officers do not presume to congratulate themselves upon this state of affairs, because our fortunate position is due to many factors, the foremost of which dates back to those early days when two of our members sensed the need of the industrial world for an organization of this sort and possessed the vision that gave it form and the courage and determination that inspired others until today we have nearly three thousand earnest members.

"Enduring success is not possible unless one has faith that the work he is doing is for a worthy cause and warrants sacrifices and laborious effort, and it is, therefore, to the individual members who are supporting most energetically the work of the various chapters and giving tangible form to the purposes of this society that your officers feel a great deal of credit for a very successful year should go.

"That there is much work yet to be done before the society fully meets the needs of its membership in general is thoroughly appreciated, and while progress from your standpoint may sometimes appear slow, it is not because earnest consideration of pressing problems by your officers is being slighted; but because we are a young, aggressive and rapidly growing institution and your officers must look well and build well as we go, in order that we may avoid the evils that befall a mushroom growth.

Sectional Meetings

"One of the earliest matters considered by the directors was some method whereby the individual members might be brought into more intimate contact with the society in general and with members in adjoining chapters in particular. It was realized that the National Convention would probably never be held in many cities in which we had chapters because of the lack of adequate meeting or exhibition facilities and that for such reason, in conjunction with the long distances to be traveled and the consequent time and expense, and a great number of our members would probably never have an opportunity to participate in any of the national convention activties; all of which tended to leave in more or less obscurity the invaluable constructive work being carried on by certain chapters and individuals in furtherance of the society's purpose. Hence, it was decided to arrange for two or more sectional meetings each year, the sections to have floating boundaries and to center about chapters that would draw attendance from cities which would probably not present facilities for the national convention. Two sectional meetings were held during the year—New York and Pittsburgh—and the successful outcome of each of these would indicate that your directors had made a wise decision and that the practice should be continued. One precaution should be emphasized, and that is it is not the intention of your officers to permit these sectional meetings to become so pretentious as to create a financial burden or an undertaking beyond the capacity of any single chapter; or to permit them to encroach upon the prestige or scope of our annual convention.

Our Transactions

"Our TRANSACTIONS are the link which binds the individual member to the national organization. Until this year the society depended upon the national convention entirely for material for the TRANSACTIONS.

The disadvantages of such a method for a monthly publication are self-evident and require no detail mention. The responsibility of editing and preparing the convention papers for publication rested almost entirely upon three men, and few, indeed, of our members appreciate the volume and importance of the work these men handled. Prof. H. M. Boylston was chairman of the Publication Committee and J. V. Emmons and E. E. Thum were the other members.

"When the fiscal year ended last September, J. V. Emmons resigned, by reason of his election as treasurer, and Prof. Boylston asked to be relieved, but kindly reconsidered and agreed to serve as chairman of the reorganized Publication Committee. With a view to distributing the work and lessening the burden upon each individual member, the Publication Committee was increased to nine members, divided into groups of specialists in the various fields of steel treating activities.

"It was evident, however, that a progressive and rapidly developing society could not continue long to conduct its monthly journal entirely upon voluntary and divided editorial direction, and depend upon the papers submitted to the annual convention for publication material. A definite scheme of development involving a publication program projected at least a year ahead whereby (1) prospective contributors might be guided in their choice of submissions and a better balance of new material for publication made possible; (2) a continuing and gradually broadening educational course might be instituted for the information and development of the practical man who wished to become acquainted with scientific principles underlying his work, but who does not want it put before him in six-cylinder or eight-cylinder language; (3) a reliable record of recommended practical and proved heat treating practices for a great variety of machine and tool parts which are common articles of manufacture throughout the country; all to the end that our scientific worker will find our publication a continual source of inspiration and of new ideas; that our practical shop members may find in it reliable information for immediate application as well as a clear and simple exposition of the principles of steel treatment and of the phenomena connected therewith; and that non-members may better appreciate the value of membership in our society.

"With such thoughts in mind and with a determination to make our TRANSACTIONS a leader in the field of applied ferrous metallurgy, your directors engaged a full time editor, who was recently introduced to you through the columns of the TRANSACTIONS. Mr. Bayless took hold May 1, and is thoroughly in sympathy with the views of your officers and promises to give material form during the coming year to the program outlined.

"Now one of the obstacles that confronted me when I tried to get a full time editor on the job was that the society couldn't afford it. My answer was, that the society couldn't afford to go along without it. I believe it was a justifiable increase in expense, and furthermore, he has saved his salary thus far. I am not for any policy of restriction, cutting down your expenses to such an extent that this society is just going to dry up and die of dry rot. We have to meet the needs for which we were organized. The only way to do that is to get the money and spend it, well and wisely. We have not obtained our full growth.

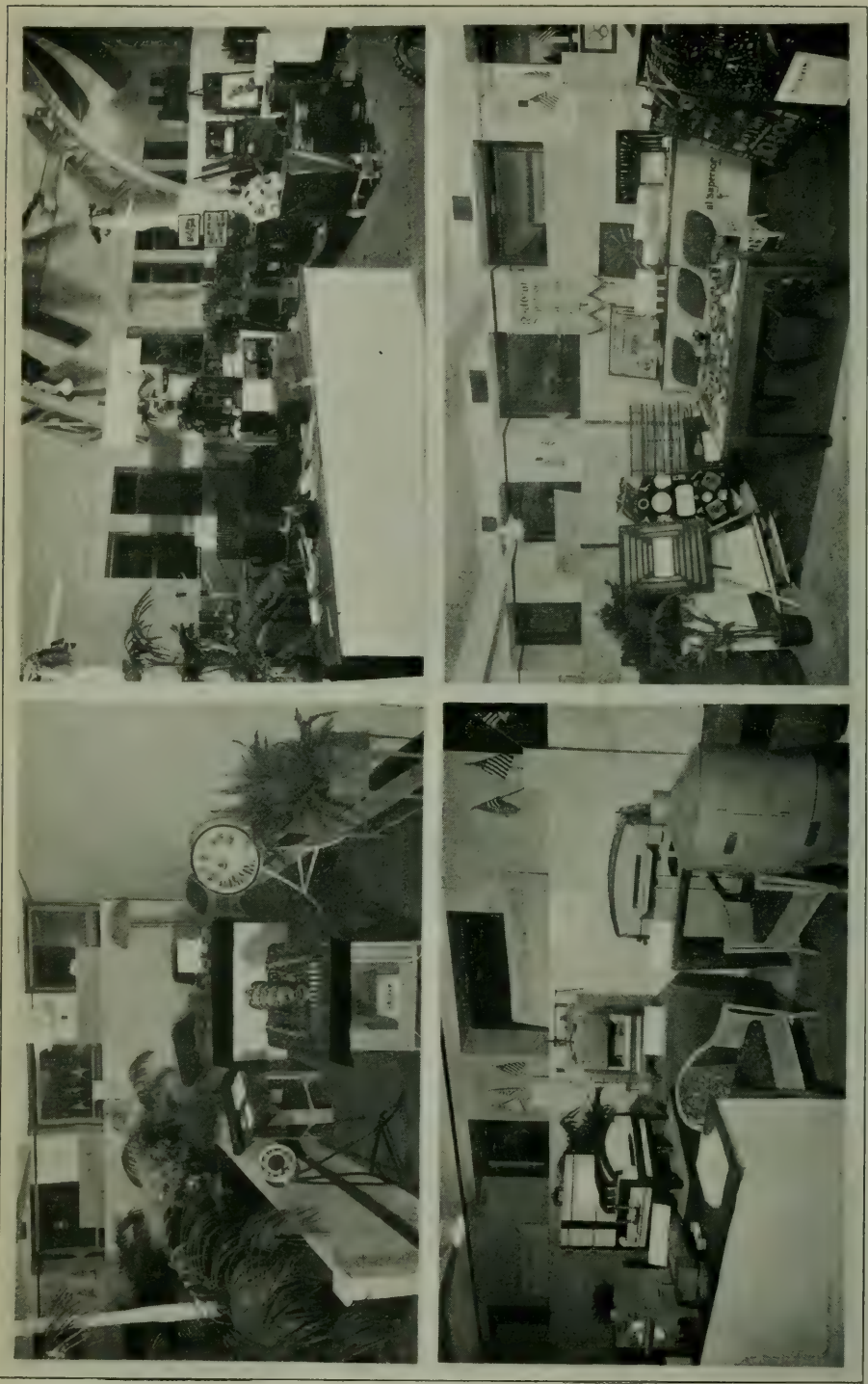
We are merely starting, and we have to build well, and we have to look out for the future. Simply because the society has five or six or seven thousand dollars today doesn't mean very much, to, at least, anyone who has had any business experience. It will take only a few months of hard times to make that minus, because in running an organization of this kind we have to contract with our printing firm. You cannot chop off expenses like that. You have obligations that, if we shut up shop tonight, you have to pay, and if we were to draw upon that surplus you would be surprised what was left. I have no argument when anybody wants to delve into our financial situation, but I do want to continue to combat that idea that we are a little bit of a thing, and we want to draw in. We want to meet the requirements of our members. The only way to do that is to go ahead and do it constructively. (Applause).

Finances

"The Finance Committee, directed by your conscientious and painstaking treasurer, is deserving of your thanks for its work during the past year. Our society has always been fortunate in its choice of treasurer. Each has left behind him a most creditable record. The work involves a great deal of responsibility and requires a very considerable amount of time and study, in order that our balance sheet may reflect no serious losses. The progress of our present treasurer has succeeded in meeting the responsibilities of his office and in inaugurating a financial program of a very high order has just been shown. Not only has a budget system been developed, but your society has operated under that system since Jan. 1, and our treasurer has demonstrated that it is not to be interpreted as a harmless warning; but that it constitutes a fundamental financial program that is respected and adhered to. The financial course of the future has been charted and the means provided whereby the detailed financial progress of this society can be determined from month to month by your directors. Thus safeguarded we should be able to cope successfully with any eventuality of the future—provided only that they who direct the activities of this organization simply read the signs as they pass along.

Membership

"When the budget system was adopted by the directors early in the year, it became necessary to scan our membership records very closely in order that the estimated income for the year might be based upon reliable data. Our membership records received a thorough inspection and the curve of total membership dipped noticeably. This dip was prevented from becoming serious by the strong efforts put forth by our secretary in co-operation with the Membership Committee. While a campaign for new members was pushed, the campaign was along conservative lines and avoided any attempt to create a growth which lacked stability. A large turnover in membership was inevitable and could not be prevented in the transition from an exceedingly busy period to one of extreme dullness, aggravated by uncertainty as to the future Now that the horizon is clearing, a continuous healthy growth should be maintained without any difficulty if the society and its various chapters will continue to concentrate upon providing its mem-



GROUP OF BOOTHS AT INTERNATIONAL STEEL EXPOSITION, GENERAL MOTORS BUILDING, DETROIT

bers with reliable and practical information on the various phases and applications of steel treating principles.

Our Chapters

"The chapters have the same relation to our society that the nerves and heart do to the human system. What benefits one benefits the other; and what adversely affects one also reacts adversely on the other.

"The most striking characteristics I observed during my visits to the various chapters was that the well being of a chapter depends to a very large extent upon the relation of its meeting program to the daily needs of its members. The majority of our members join the society with a desire to learn and a will to help the other fellow; and where the interest has lagged or the meetings have become desultory, it is simply because the officers and committees responsible for the chapter program have failed to sense or to respond to the needs of the occasion. This society has an amazing wealth of most excellent material to draw upon for our chapter meetings. It is true that some of it requires coaxing, but the results obtained have shown very plainly that it pays to have those responsible for the chapter program go to unusual ends to gain the confidence of the practical man—the artisan—and get him on his feet. We must continually keep in mind that the art of steel treating preceded the science of steel treating and that the artisan can still accomplish many things for which the scientist has yet to evolve a universally accepted explanation. Just so long as our chapters grow in their knowledge and understanding of the principles that underlie the art and science of heat treating, so long will this society continue to grow and prosper; hence, it behooves us to give very earnest consideration to the development of our chapter programs and to the selection of our chapter officers and committeemen. There are too many available men and too much available material to allow our chapter activities to suffer, although I regret to have to state that a few chapters have not advanced as they should.

"Chapter finances have been a troublesome matter in some instances. The directors have given this matter very serious consideration during the past year and made certain changes in the distribution of dues that will aid nearly every chapter in a substantial manner if it will but attempt to develop its membership possibilities. The margin between National society income and outgo is not large enough to permit the society to alter materially the present division of dues.

"Quite a number of chapters are conducting night school courses which are meeting with pronounced success. Our editor is collecting material for a series of lectures so that the National office may be in position to supply any interested chapter with material aid in connection with institution of educational courses. Northwest chapter, with a membership of about 50, had in the neighborhood of 70 members enrolled in its course when I visited it. Chicago, Philadelphia, and Worcester are carrying on similar work, as will be explained at the Delegates Session.

"If we look well after the health of our chapters and build so that the editorial staff and the TRANSACTIONS will function as the heart of the system and act as a constant source of inspiration to each chapter

and every member, we need to have little fear as to our future welfare.

Research

"One of the founders of our society emphasized the need of properly directed research in the course of an address before the Chicago chapter about four years ago. We have not yet attained the goal he set at that time, but we are on our way, under the able direction of our former president, Colonel A. E. White.

"Our Research Committee is planning to act as a clearing house; to the end that those individuals and institutions possessing talent and facilities for research may be provided with problems of practical interest and importance for solution; and, in addition, that data already in existence as a result of previous research, investigation or study by individuals outside the active membership of this society and not generally known may be collected and supplied to those in need of such special information.

"The Research Committee will hold an open session later in the week, at which time it will outline its program and report upon its accomplishments thus far. Every member is urged to consider it his duty to attend this session and aid the Committee, and the Society and serve those purposes for which it was instituted.

"And there is the place for you to express your views and opinions, regarding research. The present board of directors hasn't the slightest intention, hasn't started and doesn't intend to start, any fund to finance research on a large scale, or on a small scale, because we don't consider that any of our business.

Standards Committee

"The Standards Committee has a great responsibility resting upon it and an equally great opportunity confronting it. The members are acting wisely in delaying the promulgation of a definite program until after they have had an opportunity to confer with the membership of the society at the Standardization Session.

"Too many independent bodies are laboring on standardization work, and if great care is not exercised chaos rather than order will prevail. Therefore, it rests upon our members and the Standards Committee to consider carefully what problems are wholly within our field and what problems are only partly ours.

"There are a number of subjects that border on or are within the field of steel treating that are under consideration by other societies, such as the American Society for Testing Materials, and the Society of Automotive Engineers. These societies have been established for many years and have earned the confidence of industrial and technical leaders by their sane standardization work; whereas we have yet to demonstrate our ability and probity. Hence, it is very essential that the personnel and the program of our Standards Committee and its subdivisions should be so developed as not to hinder the progress of construction work in other technical bodies. We must be able to respond promptly and adequately when the opportunity to co-operate is presented, and we should be prepared to lead wisely and prudently when leadership is proper.

"Close observation of the workings of the Standards Committee

during the past year leads me to repeat the recommendations I made early in 1921, when a member of the committee; namely, that the Standards Committee as now organized should act solely as a directing unit. It should develop a general program of precedure and control, and should appoint a series of sub-committees or divisions made up of both practically and scientifically trained men who are specialists in the particular activity assigned to each division for investigation, consideration, and recommendation. The chairman of such sub-committees or divisions should not be restricted to members of the main Standards Committee as now organized, nor should membership on a sub-committee be restricted to members of this society, were it found at any time that competent specialists or practical steel treaters outside the society were well versed in a particular line of investigation and were willing to co-operate and aid in the promotion of the work of any unit.

"Such a scheme of organization will enable us to build up an organization that will demonstrate by worthy performance and not by the mere mandate that we are entitled to that confidence from the industrial world which is so essential for success. Once our ability to deliver the goods is proven, industry will follow the path of least resistance and turn to the A. S. S. T. when aid is desired on steel treating problems.

"This statement covers briefly the high spots in the activities of the society during the year just closing. Our secretary's report records the election to honorary membership of three distinguished laborers in the scientific world and in the field of steel treating—Henri Le Chatelier, John A. Mathews, and Elwood Haynes,—also of the establishment of the Henry Marion Howe Medal award, in honor of our former patron and honored member.

"Now the rules are not in shape for publication. The directors have to meet this week and we hope to have the announcement ready before these sessions close.

"All things considered, I believe it can be safely concluded that the record disclosed strong evidence that the quality of the society's work is steadily improving, that its sphere of influence is being gradually extended; with the result that the outlook for the future appears most promising. Definite progress cannot be made, however, without effort, and the responsibility for the attainment of a successful and influential career by this society rests upon each individual member. We must take our membership seriously, and participate actively in the work of our committees, our chapters, and our society, so that both chapter and national officers may be properly guided and supported in their labors to promote the objects for which the society was instituted.

"Now if our officers, either in the chapter or the national, are not properly directed, it is because we have small sessions like this today. I find it difficult to adequately express my thanks for the support I received during the past year, and the many friendships which I made.

"This report cannot be concluded without an expression of gratitude for the encouragement and support I have received from the members of this society during the past year. While the duties required considerably more of my time than I anticipated, I have no regrets. I enjoyed the work and appreciated the opportunities to meet the numerous chapter officers, committeemen and individual members whose unselfish

s are responsible for the growth and healthy development of our society. There were occasions when I regretted I could not spend more time with some chapters and aid them in the solution of their problems. The number of chapters and the distances to be traveled, however, make it a considerable task for one officer to visit each chapter, and the time will soon arrive when this work will have to be decreased or else distributed among other officers.

"When I became a member of the parent societies early in its life I thought the idea behind it was an excellent one; and now after visiting 29 chapters of this society and observing first hand the workings of both strong and weak chapters, my faith in the value of our work has not been diminished. All the indications point to a very bright future for this society as long as we keep before us the principles upon which it was founded and strive for the attainment of those ends.

"In closing, I desire to express my sincere thanks to our secretary, whose constant good nature and unlimited capacity for work lightened very appreciably my burdens; to our treasurer for his sound advice and invaluable aid in developing an exceptionally comprehensive financial program and businesslike control system; to our National committeemen—and in particular to the members of the Publication Research and Standards Committees—for their labors in behalf of our society; and to my fellow officers and directors for their unfailing courtesy and support in connection with many perplexing problems. To the individual members of this society, who honored me with this office and who have constantly extended their enthusiastic support, I tender my deepest gratitude and thanks. I hope my efforts in your behalf have not been disappointing." (Applause)

President-Elect Lynch: "Gentlemen, we have had the pleasure of hearing a most valuable address by our President.

"Is there any other unfinished business to come before this meeting?"

Mr. Danse: "I make it a point—it is rather out of order,—that a vote of thanks be recorded for our president, not only given but recorded for our retiring president." The motion was seconded and carried as all arose. (Applause) The meeting adjourned at 4:15 P. M.

Carburizing Section

Tuesday morning at 10:00 o'clock the first technical session was called to order by Prof. H. M. Boylston, Case School of Applied Science. The program for this session consisting of three papers was opened by H. B. Knowlton, Vocational School, Milwaukee, Wisconsin, who presented his paper entitled "Carburizing and Decarburizing in Case Hardening." The author discussed some of the factors which determine the success or failure of the process of carburizing in commercial practice. He pointed out that successful carburizing must produce a case of uniform depth in all specimens in a given furnace charge. The use of test pieces placed in the pots instead of depending entirely upon thermocouples placed in the muffle furnace was advocated. The temperatures indicated by thermocouples in a muffle furnace show only the temperature of the gases which are in turn affected by the temperature of the linings and of the charge. The temperature of the linings of the furnace and the ratio of the mass of the charge to that of the linings are important points bearing on the speed and uniformity of heating. While pyrometers may frequently fail to indicate the speed and uniformity

of heating pots of varying sizes in a furnace charge, the use of test specimens which may be withdrawn at given intervals and fractured, give an accurate check on the rate of carbon peneration. Photomicrographs were used in demonstrating that within reasonable limits the depth of penetration of carbon in the pieces contained in a given case, could be determined by this test bar method. The method has the advantage that in the event an insufficient case has been obtained, the charge can be run for a longer period of time thus eliminating the necessity of reheating pieces that show an insufficient case after the specimens have cooled.

The carbon content of the case, which is one of the most important factors in carburizing was discussed by the author. He pointed out that the amount of carbon at the surface of the material will be affected by the kind of carburizing material used, the temperature, the pressure and the method of packing as well as the rate of cooling. The author expressed a preference for the use of the microscope instead of the file test and scleroscope in determining the carbon content of the case. In discussing decarburization the author stated that the best way to control this condition was by the use of strong carburizing materials and well sealed carburizing boxes. The specimens should be placed well below the top of the carburizing material so that they do not become uncovered during heating.

The second paper of this session was entitled "Case Hardening" and was presented by Mr. A. H. d'Arcambal, metallurgist with the Pratt & Whitney Co., Hartford, Conn. The work covered by Mr. d'Arcambal's paper dealt with cyanide case hardening of specimens and the effect of nitrogen (iron nitride) in the case as it affects the final product especially in withstanding impact.

In the first part of this paper the author discusses the chemical reactions taking place in a steel treated by the cyanide process. The salient points brought out are:

1. Steels given the cyanide treatment are both carburized and nitrogenized, the resulting hardness, however, being due principally to the absorbed nitrogen, as the carbon is too low to produce file hardness. Medium carbon steels containing over .045 per cent nitrogen possess no ductility whatsoever, thus accounting for the brittleness in cyanide treated specimens. It is claimed that nitrogen causes greater brittleness in higher carbon steels than in steels of low carbon content, it is evident that it is folly to use a cyanide bath for reheating carburized specimens or as a heating medium for carbon tool steels.

2. The amount of carbon and nitrogen absorbed is dependent upon the time and temperature.

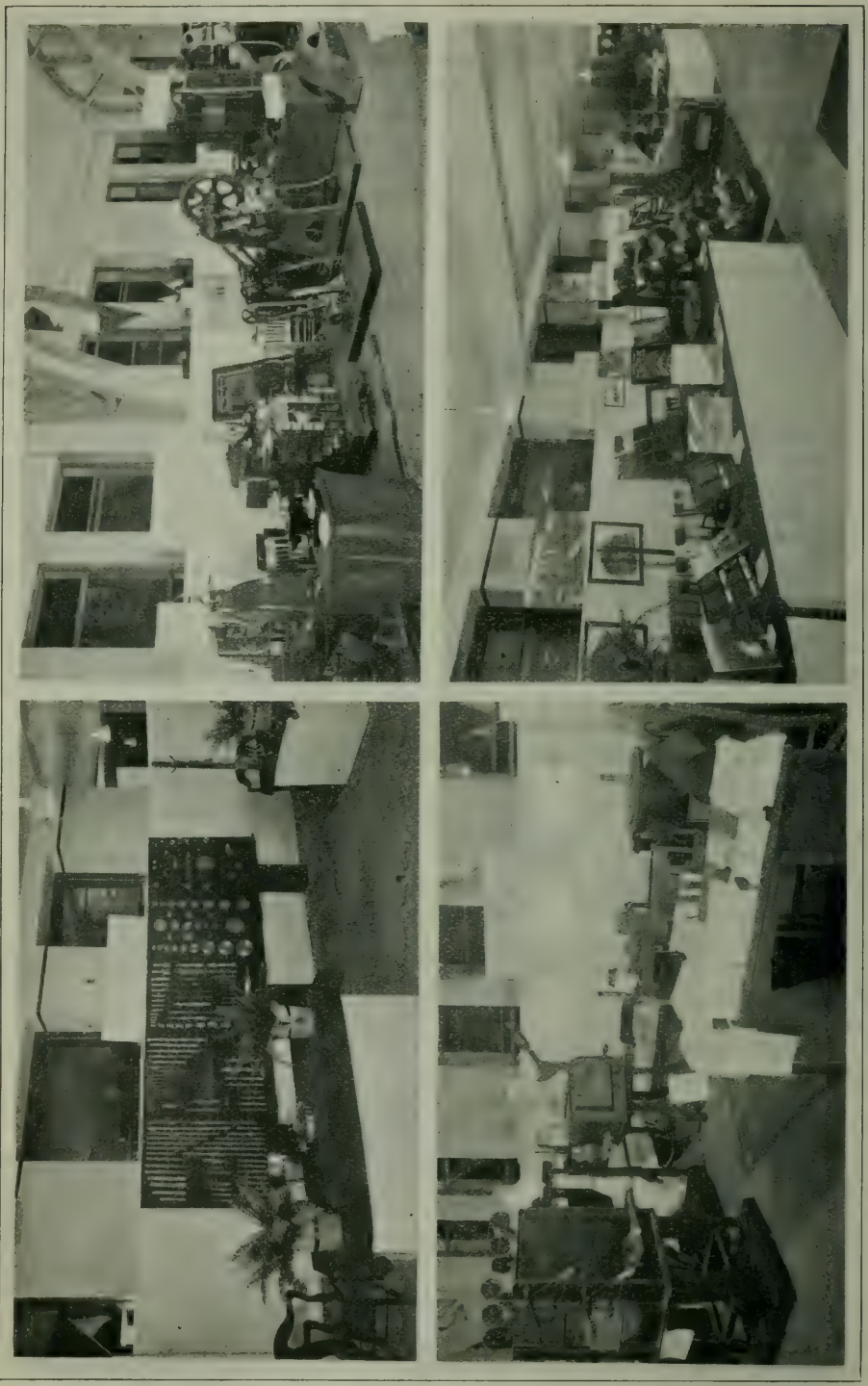
3. The highest concentration of nitrogen and carbon is found in the first .005-inch layer removed from the outside diameter of the specimen.

4. Nitrogen penetrates the material to a slight extent throughout the entire cross-section as shown by analysis.

5. Nitride needles are not found in the areas showing the highest concentration of nitrogen but are found near the breaking off point of the case. Nitrogen in the concentrated area appears as patches of pearlite.

6. The depth of case measures about the same in each of these samples, from .008 to 0.10 inch deep. Longer time at temperature does not increase the total depth of penetration but does produce a greater concentration of carbon and nitrogen near the surface.

The second part of this paper deals with Izod notched bar tests on



GROUP OF BOOTHS AT INTERNATIONAL STEEL EXPOSITION, GENERAL MOTORS BUILDING, DETROIT

several well known types of case hardening steel. The results of the notched bar tests conducted on plain carbon and alloy steels, carburized and both single and double treated, were discussed by the author. S. A. E. 6120 steels gave the highest impact values when double quenched. S. A. E. 3115 gave the lowest reading for alloy steels tested. S. A. E. 1015 and 1112 steels gave very low readings. All alloy steels showed lower impact readings after carburizing and single quenching for case refinement only, than was found on the specimens double treated after carburizing.

Impact tests conducted on the different types of steels, packed in sand instead of carburizing compound and then double and single treated. The results on these double treated specimens are in their order of magnitude from the highest to the lowest, S. A. E. 1015, 6115, 1112, 2315 and 3115.

The discussion of this paper seemed to point out that it was the general opinion that impact testing has its limitations and the method of test is not fully adapted to give comparative results on all grades of material.

Mr. E. W. Ehn, metallurgist with the Timken Roller Bearing Co., Canton, Ohio, presented the third paper of this session entitled "Irregularities in Case Hardened Work Caused by Improperly Made Steel." The author summarizes the contents of his paper as follows:

1. Failure in case-hardening, especially in reference to soft spots, is often due to improper steel. Variation of structure of a carburized piece gives a direct indication whether the steel is suitable for carburizing or not.

2. Coarse-grained structure in case and core of carburized steel with large crystals of pearlite, and clean cut cementite areas in the hyper-eutectoid zone, are signs of good or normal steel. Curly cementite, disintegration of pearlite in hyper-eutectoid zone, and fine-grain size with rounded pearlite areas in the gradation zone and core are signs of an abnormal steel. Abnormal steel has a tendency to give a thin case of high-carbon content and to form soft troostitic spots in hardening.

3. The structure of normal and abnormal steel varies with the carburizing temperature and the rate of cooling. Carburizing tests on a laboratory scale can easily be made.

4. The variation in carburizing properties is caused by oxides uniformly distributed in solid solution in the steel. The ultimate cause is improper deoxidation of the steel when made, and no later treatment can change these properties.

5. The influence of the oxides in regard to grain size is theoretically explained by their influence on the solidification of the steel in the ingot and their later obstructing action against grain growth. Disintegration of the pearlite in the hyper-eutectoid zone is caused by the solution pressure from the oxides in solution in the ferrite.

6. The formation of soft troostitic spots in hardening of abnormal steel is explained by the action of the oxide particles as starting points for the troostite formation. This explanation is founded on the investigations of Portevin and Garvin on hardening of carbon steels.

7. The results obtained in heat treatment of all kinds of steels, notably high and medium carbon steel, is dependent on the presence of oxides in the steel, and many mysterious failures, especially in hardening, are likely to find their explanation by carburizing; and a miscroscopical examination of the structures obtained.

"Carburizing on a laboratory scale with microscopical examinations is

necessary to safeguard results and more than one specimen must be taken from each lot of steel. Tight fitting containers are imperative for successful laboratory work. The variation in carburizing properties is caused by oxides uniformly distributed in solid solution in the steel which have influenced the solidification of the steel in the ingot and later obstruct the grain growth action. These oxides likewise are starting points for soft spots. The results obtained in heat treatment of all kinds of steels, notably high and medium carbon, are influenced by the presence of oxides in the steel. Failures may be reduced, especially in hardening by carburizing and a microscopical examination of the structures obtained."

Delegate Session

Tuesday afternoon at 2:00 o'clock Mr. T. D. Lynch called the delegates session to order and after roll call proceeded with the order of business outlined by the committee on arrangements.

Symposium on Metallurgical Education

At 4:00 o'clock the Symposium on Metallurgical Education was held under the chairmanship of Prof. S. L. Goodale, University of Pittsburgh. The keynote of this symposium was "not how but what to teach." Several contributions in the form of written papers or discussions were presented before the meeting which resulted in much favorable comment by those present.

Mr. H. B. Knowlton presented a paper entitled "Education of Machinists and Tool Makers in Heat Treatment."

At the same hour 4:00 p. m. a round table discussion on heat treating was held under the chairmanship of Mr. H. J. Lawson of the Cadillac Motor Car Company, Detroit. This meeting was exceptionally well attended and the discussions which were brought out were very instructive and helpful to those who were fortunate enough to have attended the meeting.

Annual Smoker

The annual smoker and entertainment was staged in the spacious auditorium of the General Motors Building at 9:30 p. m.

The program for this event was indeed well taken care of by the Detroit Chapter boys. They surely did themselves justice in their selection of entertaining features. Numerous athletic events were presented under the direction of Fielding H (Hurry-Up) Yost, Director of Intercollegiate Athletics and Dr. May, Director of Physical Education, University of Michigan. The athletic stunts, the vaudeville acts, the music, the refreshments and all were of the highest order and as evidenced by the enthusiasm of those present every one must have had an enjoyable evening.

General Heat Treating Session

Wednesday morning at 10:00 o'clock the general heat treating problems session was called to order by J. Fletcher Harper, Research Engineer, Allis Chalmers Mfg. Co., West Allis, Wis., chairman.

The program for this session consisted of five papers, the first paper en-

titled "Heat Treating in Lead," by R. B. Schenck, metallurgist, Buick Motor Car Co., Flint, Mich., was presented by the author. Mr. Schenck's paper was printed in full in the September issue of TRANSACTIONS. A brief review of this paper is as follows:

The lead pot furnace has, in recent years, been applied to volume production in steel treating with considerable success. While molten lead is far from being an ideal heating medium, it is the only metal which can be successfully employed for this purpose; and in comparison with the salts in commercial use as bath materials, it has the advantage of a much wider range of working temperature and a much higher heat conductivity. These two properties permit the use of lead in units of very large capacity for temperatures of 650 to 1700 degrees Fahr., thus covering the hardening and tempering ranges of nearly all commercial steels.

The selection of pot materials, the design of the pots and brickwork, and the method of firing are points of prime importance and must receive considerable attention if efficient operation is to be obtained. The unit should be built for the job it is intended to handle, bearing in mind at the same time the desirability of standardization.

While some parts cannot be treated efficiently in lead, there are many which can be handled very successfully. Axle shafts, transmission gears and many smaller parts are now being hardened from lead pots, and a greater number are being tempered in lead. The lead furnace has its greatest range of usefulness for tempering operations, and many parts can be tempered in lead which cannot be efficiently quenched from this type of furnace.

Comparing the lead pot with the oven furnace from the standpoint of operation cost, a great deal depends on the nature of the work handled, but in general, it can be stated that for hardening, the oven furnace is the cheaper of the two, and for tempering, the costs are slightly in favor of the lead pot.

Taking everything into consideration, the greatest argument for the lead pot furnace is the high quality of the treated product resulting from uniform and accurate temperatures. It is very difficult, if not impossible, with an oven furnace to obtain the degree of uniformity which exists throughout a lead pot. Experience covering a period of years has proven, at least to the author's satisfaction, that where conditions permit of its use, the lead pot can produce consistently better work than any other form of heating unit.

The second paper "Furnace Atmospheres and Their Relation to Formation of Scale," by Mr. G. C. McCormick, assistant metallurgist, Crompton & Knowles Loom Works, Worcester, Mass., was read by Mr. V. E. Hillman, metallurgist with the Crompton & Knowles Loom Works.

This paper records experimental data and procedure during the investigation of the scaling activity of oxidizing, neutral and reducing atmospheres during the heat treatment of steel. The scale which was formed on low, medium and high carbon steels when heated to various temperatures and under varying conditions of furnace atmospheres, has been determined quantitatively. Under certain conditions, oxidizing neutral and reducing atmospheres permit of the formation of scale. This conclusion is supported by the data obtained and may dispel some popular misconceptions.

The third paper of this session entitled "Thermal Transformations of some Chrome Vanadium Steels" by J. S. Vanick metallurgist with the

Fixed Nitrogen Research Laboratory, Bureau of Standards, Washington, D. C., was presented by the author.

This paper described the effect of varying amounts of carbon, chromium and vanadium in a typical chrome-vanadium steel, upon the thermal transformations in the steel. The transformations occurring upon heating and cooling as well as the relation of these transformations to structure and hardness were discussed. This paper will appear in a later issue of TRANSACTIONS.

The fifth paper was presented by its author C. L. Ipsen, designing engineer, Industrial Heating Department, General Electric Co., Schenectady, N. Y., entitled "The Selection of Electrical Furnace for Steel Treating." Mr. Ipsen is recognized as an authority on electrical heating furnaces and presented some of the latest information and data in reference to them.

Joint Meeting with the American Drop Forging Institute

At 2:00 p. m. Wednesday a joint meeting of the American Society for Steel Treating and the American Drop Forging Institute was called to order by the chairman. The first paper was presented by the author, Walter G. Merritt, of New York City, entitled "Some Fundamentals with Respect to the Labor Question." Mr. Merritt having had much experience as an organizer was in a position to speak with authority upon this timely subject.

Following Mr. Merritt's paper, Mr. Felix H. Levy, of New York City, delivered his paper entitled "The Menace of the Sherman Act to the Country, and How it Should be Amended."

Mr. Levy was Special Assistant to the Department of Justice under Theodore Roosevelt and has participated in many important proceedings under the Sherman Act. This paper was received with much interest and brought out many points which perhaps were not clear to many of Mr. Levy's audience.

Each of these worthy papers will be published later in TRANSACTIONS.

Round Table Discussion

At 4:00 p. m. Mr. John J. Halbing, assistant superintendent of heat treating, Ingersoll Rand Co., Phillipsburg, N. J., called the practical round table discussion meeting to order. This meeting similar to the one held Tuesday, brought out many points of discussion and interest to those attending.

Carnival, Frolic and Dance

As guests of the Detroit Chapter all those attending the convention were invited to attend the Carnival, Frolic and Dance held in the Auditorium of the General Motors Building. The party started about 9:30 p. m. and lasted until 1 a. m. A large number of persons were present and we are sure that all had a wonderfully fine time.

The hall was prettily decorated and lighted, the music was excellent and everyone was in the humor, consequently we all enjoyed a splendid evening.

Tool Steel Session

Dr. C. M. Johnson, director of research, Crucible Steel Co. of America, Park Works, Pittsburgh, as chairman, opened the tool steel meeting at 10:00 a. m. Thursday. This was one of the most interesting sessions held.

Considerable interesting discussion followed each paper. Had it not been for the short amount of time assigned for the discussion of each paper, considerably more discussion would have resulted, as evidenced by the keen interest shown in these papers.

The program for this session consisted of four papers, the first of which was presented by Mr. H. J. French, physicist with the U. S. Bureau of Standards, entitled "Lathe Breakdown Tests of Some Modern High-Speed Tool Steels." This paper was written jointly by Mr. H. J. French and Mr. Jerome Strauss, chief chemist United States Naval Gun Factory.

The paper was an exhaustive report giving the results of hundreds of breakdown tests on high-speed steel lathe tools. This paper was published in September TRANSACTIONS. An abstract of it follows:

This report is concerned with comparisons of performance of modern high-speed tool steels in so-called "lathe breakdown tests," in which the endurance of tools is measured under definite working conditions, and likewise with the limitations of this method when applied to the purchase of steel. The modern steels are first classified according to chemical composition and this division made use of in discussion of results obtained.

Important features developed or conclusions drawn may be summarized as follows:

1. Breakdown tests are not satisfactory as the basis of purchase for high-speed tool steels.
2. While competitive comparisons of brands of nearly similar performance are not justified, owing to the qualitative nature of this type of test, relatively large differences may be ascertained with certainty providing sufficient tools are tested and averages of at least 2 grinds are used in the interpretation of results.
3. In certain severe breakdown tests with roughing tools on 3 per cent nickel steel forgings, in which high frictional temperatures were produced, it was found that the performance of commercial low-tungsten high-vanadium and cobalt steel was superior to that of the high-tungsten low-vanadium type and special steel containing about ¼ per cent uranium or ¾ per cent molybdenum. The average power consumption in all cases was practically the same so that this factor need not be introduced in comparisons which may be made on the basis of endurance of the tools.
4. Modification in test conditions including small changes in tool angle but principally changes in cutting speed more markedly affected the performance of steel containing cobalt or special elements such as uranium or molybdenum than that of the basic types (plain chromium-tungsten-vanadium steels).
5. The relatively poor endurance of the high tungsten steels under severe working conditions was not observed in more moderate tests, made on the same test log with equal cutting speed and depth of cut but with reduced feed, in which the frictional temperatures produced were not so high. Also in these latter tests the performance of the cobalt steels was better than either the low or high tungsten steels.
6. Hardness determinations and examination of fractures indicate that the various types of commercial high-speed steel show differences in behavior under heat treatment and in physical properties

which probably are of importance under moderate working conditions, and might counterbalance slight advantages in performance.

The second paper was presented by Col. A. E. White, Director of Engineering Research, University of Michigan. His paper was entitled "Carbide Segregations in High-Speed Steel." In brief the author's paper pointed out that the degree of segregation in high-speed steel depends upon the casting temperature, the rate of cooling the ingot and the degree of mechanical reduction on the mills. He stated that the manufacturers of steel were cognizant of these controlling factors and that they are attemping to control them to eliminate as far as possible segregations in the final product.

The author stated that the time was ripe for experimental work in this field, along lines somewhat more drastic than had been the case in the past. The user of tool steels usually has given little attention to these matters,

FOURTH ANNUAL BANQUET OF THE AMERICAN SOCIETY FOR

his attention being from a complaintive rather than a constructive standpoint. The useful life of a tool rests as much in the hands of the user as it does in the hands of the manufacturer. Its life depends upon many factors, chief among which are the proper form of cutting edge, the rate of feed and the speed at which either the tool or work is moving as well as the necessity of proper lubrication. Col. White indicated that the next few years will bring about fundamental improvements in the manufacture of high-speed steel and that it was necessary that the consumer and manufacturer work closely together.

Mr. J. V. Emmons, metallurgist, with the Cleveland Twist Drill Co., Cleveland, presented the third paper of this session entitled "The Effects of Structure Upon the Machining of Tool Steel." This paper was published in full in September TRANSACTIONS.

In brief Mr. Emmons' paper discusses the effect of the hardness and the

STEEL TREATING IN THE BALL ROOM, HOTEL STATLER, DETROIT

structure of tool steel upon its machinability. Detailed observations have been made of the effect of the various structural constituents upon its machinability. The machining operations considered are turning, milling, drilling, reaming, thread cutting, swaging wire drawing, punching and shearing.

General conclusions are drawn as to the most favorable structures for the various machining processes. Explanations of many of the difficulties encountered in machining tool steel are offered, and the way is pointed out for the development of annealing processes to secure the desired machinability.

Some very valuable and interesting discussion followed this paper. Considerable emphasis was laid upon the fact that brinell hardness was not necessarily a criterion as to the machinability of the steel. The printed discussion of the paper will appear in a later issue of TRANSACTIONS.

The fourth paper of the tool steel session was presented by the author, Dr. N. B. Hoffman, metallurgist with the Colonial Steel Co., of Pittsburgh Dr. Hoffman's paper was entitled "A Metallographic Study of Hollow Drill Steel."

This paper gave a brief account of the severe duty that a hollow steel rock drill must withstand in everyday service. Until recently the material from which these drills were made was plain carbon steel. During the past 2 years attempts have been made to market alloy steels for this purpose, but the results have not been entirely satisfactory, owing to the fact that the steels were submitted to the blacksmith on the job in the field who were not equipped with proper means of heat treating these tools after forging, nor are they familiar with the characteristics of alloy steels. Dr. Hoffman's paper will be published later in TRANSACTIONS.

The last paper for this session was presented by the author, Mr. J. S. Vanick, metallurgist with the Fixed Nitrogen Research Laboratory, U. S. Bureau of Standards, Washington, D. C. The title of the paper was "The Deterioration of Steel and Wrought Iron in Hot Gaseous Ammonia."

Dedication of Kelly Memorial Tablet

Thursday afternoon was the appointed time for the dedication ceremonies of the William Kelly Memorial Tablet erected at Wyandotte, Michigan. These ceremonies were witnessed by many members and guests of the society. The account of the occasion appears elsewhere in this issue of TRANSACTIONS.

Coincident with the dedication ceremonies a technical session was held in the General Motors Building. This meeting was called to order by the chairman, Mr. A. W. F. Green, chief of laboratory, with John Illingworth Steel Co., Philadelphia, Pa.

The paper scheduled for this meeting, entitled "Some Failures in Aircraft Plane and Engine Parts," by J. B. Johnson, Acting Chief, Material Section, War Department, Air Service, McCook Field, Dayton, O., and Samuel Daniels, metallurgist with the same service, Dayton, O., was presented by title.

As this was the only paper scheduled for this session, chairman Green suggested that instead of adjourning that the assembled members discuss several questions of importance in respect to the fatigue failure of metals. This was agreed to and a very valuable discussion resulted.

At 4:00 p. m. the last round table discussion on heat treating problems was held. The meeting was very well attended and much interesting discussion was developed.

Annual Banquet

The annual banquet of the Society was held Thursday evening, October 5th, in the Ball Room of the Hotel Statler. This banquet was the largest in the history of the society. The American Drop Forging Institute and the Drop Forge Supply Association united with the American Society for Steel Treating on this occasion. At the speaker's table were seated the officers and guests of honor of each of the societies, including the past officers, the present and incoming ones. William C. Kelly, son of the William Kelly who was honored at Wyandotte earlier in the day, was present at the speaker's table.

President Gilligan, American Society for Steel Treating, was chairman of the evening, and after his opening address presented Charles T. Bragg, the toastmaster of the occasion.

Mr. Bragg proved to be a very capable and entertaining toastmaster. He presented Mayor Couzens, of Detroit, who made a short speech of welcome to the guests of Detroit. Following Mayor Couzens, Frank H. Alfred, President of the Pere Marquette railroad, presented a very able address entitled "What Is the Matter With the American Railroads Today?"

Mr. Alfred's address is published elsewhere in this issue of TRANSACTIONS.

A masterly address was delivered by Marion L. Burton, President of the University of Michigan, Ann Arbor, Michigan, entitled "That Mind of Yours." Dr. Burton, after drawing numerous word pictures and relating several anecdotes developed in a very forcible way the importance of man's mind to his own success and consequently to the success of the nation.

Dr. Burton's address is published on other pages in this issue of TRANSACTIONS.

Prior to the two principal addresses of the evening, W. H. Eisenman, National Secretary of the Society, presented Frank P. Gilligan, retiring president, with a gold watch and chain as a small token of the Society's appreciation for the untiring efforts he put forth in making his administration a successful and productive one.

On behalf of the Board of Directors of the Society, Col. A. E. White presented certificates of Founder Memberships to Messrs. Theodore E. Barker and William P. Woodside, each of whom were responsible for the organization of the two original societies which were brought together and made one—The American Society for Steel Treating.

Friday Morning Technical Session

Chairman R. S. Archer, metallurgist with the Aluminum Company of America, Cleveland, O., called the morning technical session to order at 10:00 o'clock.

Two papers were scheduled for this session, the first entitled "Heat Treatment and Properties of Duralumin," by H. C. Knerr, metallurgist with the Naval Aircraft Factory, Philatelphia, Pa., was read by the chairman. Considerable interesting discussion followed the reading of this paper. Mr. Knerr's paper was published in the October issue of TRANSACTIONS. The discussions will be presented in TRANSACTIONS at a later date.

The second paper entitled "Rapid Graphitization of White Cast Iron and a Discussion of Resulting Products," by Dr. Anson Hayes, Professor

of Chemistry, and Prof. W. J. Diedricks, Asst. Prof. of Mechanical Engineering, each author being faculty members of Iowa State College.

Dr. Hayes presented his paper and brought out some important points on the rapid graphitization of cast iron. An interesting discussion followed the presentation of this paper and will appear in a future issue of the TRANSACTIONS, together with the paper.

Symposium on Hardness Testing

One of the most interesting and important of the three symposiums held during the convention was the one dealing with hardness testing, which was presided over by Major A. E. Bellis, president, Bellis Heat Treating Co., New Haven, Conn. This symposium was under the direction of the Hardness Testing Committee of the National Research Council.

Major Bellis presented briefly the objects of the committee, commenting upon the results of investigations along this line. The questionnaire which appeared in September TRANSACTIONS had assisted in a material way in gathering data and ideas of other men. Following the introductory remarks of the chairman, Dr. H. P. Hollnagel, General Electric Co., Schenectady, N. Y., presented his paper entitled "Significance of Hardness Tests." Dr. Hollnagel pointed out that there was a great diversity of opinion as to just what "hardness" was. He stated that there are two classes of hardness, superficial and penetration. In discussing the numerous methods for determining hardness, he classified them as falling under the following:— scratch, resistance to wear, rebound, bending, penetration impact and deformation.

The second paper entitled "Hardness and Its Relation to Magnetic Properties," by Prof. R. S. Williams, Oberlin College, was presented by title.

Research Session

Last year at the Indianapolis convention the first research symposium was held. This year the second one was scheduled with some very interesting papers presented by men who are regarded as authorities on the subject. The meeting was called to order at 2:00 p. m. by the chairman, Col. A. E. White, Director of the Department of Engineering Research, University of Michigan. The papers which were presented are as follows: "Research for Engineering Societies" by A. D. Flinn, chairman division of engineering, National Research Council, New York; "Government Research" by W. M. Corse, vice chairman division of engineering extension, National Research Council, Washington; "Some Fundamentals of Research" by F. O. Clements, division of research, General Motors Corporation, Dayton, Ohio, and "The Executive and Research" by Dr. John A. Mathews, president Crucible Steel Co. of America, New York.

Two of these papers appear in this issue of TRANSACTIONS.

Plant Visitation

Many members and guests availed themselves of the opportunity of visiting several of the Detroit automobile plants throughout the week. A generous list of plants were open to the inspection of the members of the Society, chief among which were the following:

The Ford Motor Co., Highland Park Plant; the Ford Motor Co., River

Rouge Plant; the Cadillac Motor Car Co.; the Central Forge and Gear Co.; the Lincoln Motor Car Co.; the Detroit Steel Products Co.; the Detroit twist Drill Co.; and the Hudson Motor Car Co.

Automobiles were furnished by several of the automobile manufacturers in the city for the transportation of visitors to the various plants.

Visiting Ladies Entertainment

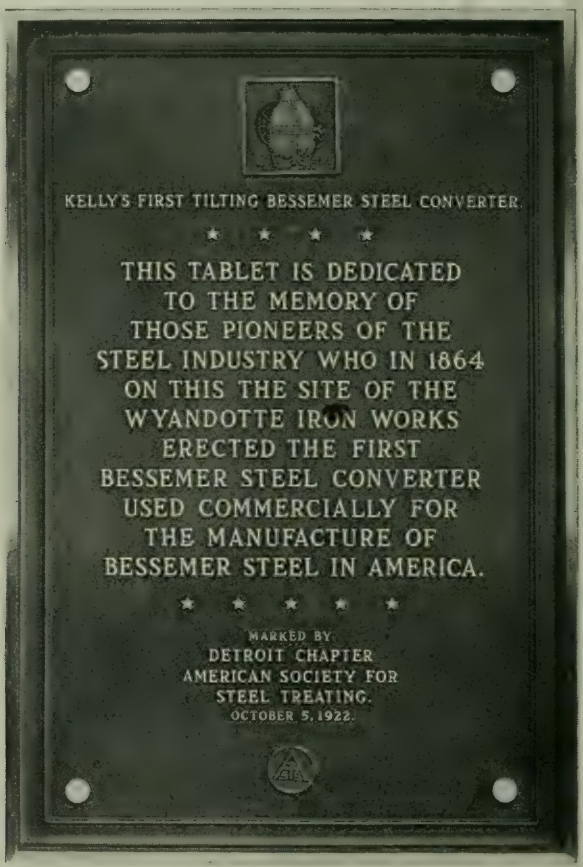
The visiting ladies were royally entertained during their stay in Detroit. The committee on arrangements had prepared a very interesting and attractive program which was enjoyed by upwards of 100 out-of-town ladies.

The first event was a luncheon held at the D. A. C. Tuesday noon, at which time the ladies were given the opportunity of meeting in a body. Each day was well occupied with motor trips, theatre parties, dancing parties and finally the annual banquet of the Society held Thursday evening in the Ball Room of the Statler Hotel.

From all of the reports we have heard, the ladies had a very enjoyable time while they were in the Auto City.

THE DEDICATION OF BRONZE TABLET TO THE MEMORY OF WILLIAM KELLY

Thursday afternoon, October 5th, a rather large delegation of members and guests of the Society, proceeded to Wyandotte, Michigan, a city located on the Detroit river about 15 miles below Detroit, to participate in the dedication ceremonies of the bronze tablet to the memory of William Kelly, iron master and scientist, who is credited with being the first and the original



Courtesy of *Iron Age*

The Kelly Memorial Tablet

producer of steel in the United States by means of a pneumatic converter. The tablet was erected by the Detroit Chapter of the American Society for Steel Treating and is placed on the outside wall of the public library, which now stands on the site of the Wyandotte Iron Works where in 1864 William Kelly's first tilting converter operated.

The occasion was made a general holiday for the town. A parade of all school childen marched through the main street, headed by a large band, and assembled in front of the library for the ceremonial exercises. Several white-haired citizens of Wyandotte, the last of the workmen who had la-

bored in the plant where Kelly made his steel, were seated on the speaker's stand erected in front of the library.

Captain Robert W. Hunt of Chicago who in his earlier days had worked with William Kelly in developing his process and William C. Kelly of Charleston, W. Va., son of William Kelly were guests of honor who presented speeches during these ceremonies. Col. A. E. White, past president of the Society made the dedicatory address followed by the unveiling of the tablet.

The ceremonies were opened at 3:45 p. m. by J. L. McCloud, chairman of the Detroit Chapter who presented President Frank P. Gilligan, of the American Society for Steel Treating, master of ceremonies of the occasion.

President Gilligan's Introduction

"It is an honor to preside at an occasion like this, arranged to recognize in a formal manner, and to perpetuate the memory of one of the industrial pioneers of this country. And in this connection I think it is only fitting to read a communication received from one of the steel pioneers of England, Sir Robert Hadfield:

22, CARLTON HOUSE TERRACE,

Dear Sir,

I notice that you have very thoughtfully decided to erect a tablet to commemorate the establishment of the first Bessemer Converter in America, on the site where Kelly's first tilting Bessemer Steel Converter was erected. I note this site is now occupied by the Wyandotte Public Library.

Provided the scheme is completed perhaps you will kindly let me have some printed matter about it, also photograph of the tablet with the wording, which I should like to have amongst my historical papers. If it is possible to send me two copies of the proceedings relating to the Unveiling exercises on October 5th, giving the speeches, and other information, I should be much obliged.

If this letter should reach you, previous to the exercises taking place, may I as an Englishman, and as one of the Honorary Members, offer heartiest congratulations on the greatness which William Kelly achieved in his pioneer work. All honor to such men.

With best wishes for the continued progress and prosperity of your Society.

Yours faithfully,

(Signed): R. A. HADFIELD

The Secretary,
American Society for Steel Treating,
Cleveland,
Ohio.

"It gives me pleasure to introduce the National President-elect of the American Society for Steel Treating, Mr. T. D. Lynch.

Pres. Elect Lynch: "Ladies and gentlemen, it certainly gives me great pleasure to appear before you, to honor a man whose honor is due him. William Kelly was an American scientist who completed his work in 1888, at the advanced age of 77. He wrought well and left an inheritance and a stepping stone for greater things. He was born in Pittsburgh, Pa., edu-

cated in the public schools, and spent his early life in that smoky city. At the age of 33 he moved to Lyon County, Kentucky, to work in the iron industries there. Being of an aggressive turn of mind and of research disposition, he began experiments on the important problem of reducing the fuel cost in the manufacture of iron and steel. This, in turn, led him to the study of the special problem of decarburizing molten iron by the air blast, which he accomplished in 1847. Mr. Kelly took out patents in this country in 1856 and built his first converter at Wyandotte on this ground in 1864. Here this great invention was demonstrated commercially, and here, by the courtesy of the Detroit Chapter of the American Society for Steel Treating, we, his followers, and with us one of his compatriots, Captain Hunt, who will speak to you later, have the pleasure of honoring him.

"The problem of steel making, like all other developments, has come to us in steps. One problem was solved, and then another; the molten iron refined from the ore and the bar forged from the nugget marked the beginning. Then came the crucible process of making steel, invented by Huntsman, a watchmaker, in 1742, to serve the special need for a material from which to make watch springs and tools. This process, while limited in quantity production, produced a steel the excellency of which hasn't been surpassed to this day.

"One hundred two years later, 1864, Mr. Kelly's converter process was demonstrated and the manufacture of converter steel on a quantity basis was begun, marking the beginning of the use of steel on an extensive scale, or the arrival of the age of steel.

"The open hearth and the electric furnace processes followed, and today steel is made commercially by all of these processes, varying in quality, carbon content and alloy elements. The limitless variety of merchantable steel available for various purposes, the proper thermal treatment for rendering this suitable for use, and the judicious application of these steels in design, together with their corresponding proper treatment, are problems of great importance. Our Society, the American Society for Steel Treating, has for its aim, and is working on, the solution of many of these problems by the exchange of experiences, free discussion of various treatments of different steels and the correlation of results, found both by experiment and in service, and desire to bring this data to the attention of the members of our society, and through them, by means of our printed publication—TRANSACTIONS, to educate the public, and thus do our part in harmonizing the science of heat treating steel for the benefit of mankind.

President Gilligan: "Prominent in that long list of leaders who have helped put this country in the first position are the names of Kelly, Jones, Hunt and innumerable others. Today we have the pleasure of Captain Hunt's company, and it gives me great pleasure to introduce him to you."

Captain Hunt's Address

"Mr. Chairman, ladies and gentlemen, it is needless to say that I take great pleasure in being here, and I am also free to say to you that if it were not pointed out to me that this is the location of the steel plant with which I was connected many, many years ago, I should not have recognized it.

"It is 57 years since I first came to the experimental pneumatic—Kelly process-steel plant, located where we are today dedicating this tablet.

"Not relying upon my memory for the details of the Wyandotte Rolling

Mill Company's plant, as it then existed, I depend upon the American Iron & Steel Association's Directory of the Iron and Steel Works of the United States, and it is there stated that the Eureka Iron & Steel Company had two blast furnace stacks at Wyandotte, Michigan, furnace No. 1, built in 1855, was a stack of 50 feet by 12 feet and was rebuilt in 1884 and 1885, while furnace No. 2 was 45 feet by 9 feet, built in 1863, and was originally called the Ward Furnace.

"The two furnaces were built side by side, with their casting houses covered by one roof, and it was adjoining the casting house of No. 2 furnace, which was the southernmost of the two, that the experimental Kelly Process plant was built.

"The authority above quoted states that the rolling mills were built in 1855, with five double and five single puddling furnaces, 12 forge fires, 11 heating furnaces, 6 trains of rolls, 8, 10, 18, 20, 24 and 30 inches respectively, and one five-ton hammer. The products of the mills bearing the brand of 'Wyandotte' consisting of boiler plate, tank iron and merchant bars.

"The Swedes were among the earliest users of the pneumatic, or as they called it, the bessemer process, to achieve commercial success with it, this undoubtedly, was largely due to the low phosphorus and sulphur content of their ores, which were then smelted with charcoal, and used the iron directly from their blast furnaces for the conversion into steel by the bessemer process. Undoubtedly, the selection of Wyandotte for the location of the experimental steel plant was largely on account of the production there of charcoal pig iron from the pure and rich Lake Superior ores, and that belief is strengthened by the fact that the first iron to be treated in the steel plant was taken directly from the Eureka, or No. 1 blast furnace.

"Going back of the history of the steel plant, it is an interesting fact that, undoubtedly, Wyandotte was selected for the location of the blast furnaces and rolling mills because of the cheap water communication with the Lake Superior iron ore region, and the fact that the surrounding country was covered with desirable timber for the making of the charcoal to be used in the reduction of the ores. At all events, the furnaces did depend upon the supply of wood in this immediate locality, and it was following the exhaustion of that supply that their operations ceased."

"This is not the time to go into the complete history of the invention or the introduction of the manufacture in this country of steel made by the pneumatic or Kelly—Bessemer Process—now universally known as the Bessemer Process.

"This experimental plant was owned by Capt. E. B. Ward, of Detroit, the principal owner of the Wyandotte Iron Works, the Cambria Iron Company, Johnstown, Pa., Lyon Shorb & Company and Park Brothers & Company, of Pittsburgh, Pa., and Z. S. Durfee, and later Messrs. Chouteau, Harrison & Valle, of St. Louis, joined the combination, which was known as the Kelly Pneumatic Process Company, and was operating under U. S. patents which had been issued to William Kelly, of Eddyville, Ky. Later, they also secured Mushet's American patent on recarbonization, No. 17389, dated May 26, 1857, Letters Patent for the same having been taken out in England on September 28, 1856.

"It is historical that previous to the application of William Kelly for a patent, Henry Bessemer, of England, had taken out U. S. patents, dated February 16, 1856, and August 25, 1856. Subsequently Kelly claimed priority

in the discovery of the principles of the process, and our patent office allowed his claim by granting him patents.

"It was constructed under the supervision of Mr. William F. Durfee, a talented mechanical engineer, and from plans prepared by himself, and it was under his personal direction that the first heat of steel was made in the fall of 1864 from direct blast furnace metal, and it was the first heat of steel made in America by the pneumatic process, and it was also, of course, the first heat of such steel to be made in this country from direct blast furnace metal.

"Another experimental plant was built under the direction of A. L. Holley, in Troy, New York, for the firm of Winslow, Griswold & Holley, and based upon Bessemer's American patents, for process and machinery including the tilting converter, but they did not make a heat of steel until February 16, 1865, while Mr. Durfee, at the Wyandotte plant, had made his first blow in the preceding fall. The Troy conversion was of remelted pig iron Mr. Durfee soon had the assistance of Mr. Lewellen M. Hart, an Englishman, who had acquired some experience in the business at the works of Messrs. Petin, Gaudet & Company, in France. Upon Mr. Hart's recommenation, a reverberatory furnace was built for the purpose of melting pig iron for the charges to be used in the conversions, and mixtures of English and American irons were used. The works remained under Mr. Hart's direction

VIEW SHOWING THE CROWD WHICH ASSEMBLED IN FRONT OF THE WYANDOTTE PUBLIC LIB

until the beginning of 1865, when he severed his connection and went to the Troy works. He subsequently went to the Pennsylvania Steel works, at Harrisburg, Pa., and afterward engaged in other business in Philadelphia, where he died.

"In March, 1865, Mr. Ignatius Hahn assumed charge of the Wyandotte works. He had lately arrived from Prussia, where he had been in the works of Krupp, at Essen.

"Following my return from soldiering in 1865, to resume my duties for the Cambria Iron Company, at Johnstown, Pa., they decided to send me to the Wyandotte plant, so that I might prepare myself to take charge of a steel plant, if they determined to build one at Johnstown. This brought me here early in May, 1865. I reported to Messrs. Durfee and Hahn.

"There were many manufacturing difficulties encountered in the operation of the plant, particularly in the matter of refractories, tuyeres, etc. The 2½-ton converter did not have a removable bottom—Holley had not yet invented that improvement—and hence the vessel had to be cooled off sufficiently to allow workmen to crawl into it to repair a defective bottom or make a new one. Moreover, William F. Durfee had been much hampered in his construction plans by having to keep away as much as possible from anything controlled by the Troy Bessemer people. At all events, matters did not go

RARY TO HEAR THE MEMORIAL DEDICATION CEREMONIES IN HONOR OF WILLIAM KELLY

very smoothly, and Mr. Hahn, on July 4, 1865, unexpectedly and peremptorily resigned and left the place.

"Capt. Ward sent for me to come to his office in Detroit, and asked me if I thought I could run the place. I replied to him that I could, at least, do what, so far, I had only seen others do—make failures. He laughed and said, 'All right, go at it.'

"By some great good luck, my first blow on July 7th or 8th, 1865, was a successful one, and I stayed on the job until May 14, 1866, when the Cambria Company called me home to Johnstown, as they thought they were ready to commence the building of their own steel plant, but through various causes we did not get that plant started until July 10, 1871. Upon leaving Wyandotte, I turned over the management of the works to A. S. Aubrey, who had been connected with them during practically all of the time from their first building, and I believe he remained in charge until they were finally abandoned.

"Not only was the first heat of pneumatic steel to be made in America produced in the Wyandotte plant, but the first direct blast furnace metal to be converted in America was here treated. The first metal to be converted, which had been remelted in a cupola, was here blown, the metal having been melted in a cupola in a foundry belonging to the iron works, standing outside of the casting house of No. 2 blast furnace (this was under Z. S. Durfee's direction.) The metal was run in an open gutter to the converter, and hence became too cold for satisfactory conversion, but based upon the partial success then attained, it was decided to abandon the remelting air furnace and erect a McKenzie cupola, which was done in the fall of 1865, and while the regular supply of metal treated came directly from the blast furnace, the cupola was used to melt whatever irons were sent to the plant for trial.

"Another 'first' of great importance was the rolling of the first steel rails in this country in the iron rail mill of the North Chicago Rolling Mill Company, before a company of prominent iron and steel men, on May 24, 1865, from steel blooms hammered under the Wyandotte 5-ton steam hammer, from ingots cast in the experimental steel plant. These rails were subsequently laid in the track of the Chicago & Northwestern Railroad where they gave good service. There were not many of them, but they thoroughly demonstrated the practicability of American steel rails.

"Still another of the many 'firsts' to be made at the plant was the use of 'bottom casting' of ingots, and also the use of ingot moulds with the large end up. Many problems were met and most of them solved.

"A stationary converter was constructed in 1865 to avoid the Bessemer tilting converter patent. This was successfully tried, but about this time the patent controversy, between the Kelly Process Company and Winslow, Griswold and Holley was ended by a consolidation of the two interests in a new organization, in which the Troy or Bessemer people received 70 per cent and the Kelly, or Wyandotte people, 30 per cent. John A. Griswold, John F. Winslow and Daniel J. Morrell, being trustees, and Z. S. Durfee General Agent. This action cleared the business atmosphere and a number of licenses were taken and plants of larger capacity were rapidly erected. Captain Ward bought the Wyandotte experimental plant from his associates, but it was not adapted for commercial competition and was, in a comparatively short time abandoned. Moreover, Captain Ward was largely interested in the North Chicago Rolling Mill Company and that company built an up-to-date Bessemer plant which started operations in 1871. This plant, after many years of successful operation, was abandoned, the North Chicago Company transferring

the scene of their operations to South Chicago, the works there built being now a part of the United States Steel Corporation holdings. So has time brought many and great changes."

President Gilligan: "Among the many interesting contributions received by your committee, one from one of the prominent shipbuilders is of particular interest. 'It may interest your Mayor and his guests to know that the first steel steamer built in America was the tug boat Sport, built at

Col. A. E. White Unveiling the Kelly Memorial Tablet

Wyandotte in 1871-72 and that she was built of the steel products resulting from the experimental work which was not of sufficiently uniform character to be marketable. There was a pile of ingots in the mill yard which I had rolled into plate, from which I got more than enough good stuff to build the boat. I sold the surplus to the Detroit Safe Company. I saw the Sport in Port Huron a few years ago. She was 45 years old and in good condition.

Signed—FRANK KIRBY.'

"It gives me pleasure to introduce Col. A. E. White, past President of the American Society for Steel Treating, who will dedicate the tablet."

Col. White: "Mr. Chairman and guests, ladies and gentlemen, in behalf of the Detroit Chapter of the American Society for Steel Treating, it gives me pleasure to dedicate this tablet to the memory of those pioneers of the steel industry who, in 1864, on this, the site of the Wyandotte Iron Works, erected the first converter used commercially for the manufacture of steel. With deep appreciation that our present-day civilization is in no small measure built upon the work of such pioneers as William Kelly, whose son we are honored to have with us today. We bow in deep appreciation and gratitude to the memory of such a man, and acknowledge with full significance our debt because of his accomplishments.

"To you, Hubert Amiot, representative of the City of Wyandotte, we entrust the keeping of this tablet. May it remain throughout the coming generations as a memorial to the work and genius of Mr. William Kelly and

as a continual source of inspiration to the youth of America."

President Gilligan: "I am pleased to introduce a citizen whom you well know, His Honor, Mayor Amiot of Wyandotte."

Mayor Amiot: "Mr. Chairman and delegates of the American Society for Steel Treating, attending guests, and citizens: I am indeed honored in accepting on behalf of the City of Wyandotte this historical tablet which is placed here in remembrance of one of the things in past industrial history in Wyandotte, the first making of bessemer steel in America, of which our citizens are proud. In behalf of the city and in behalf of the iron and steel workers who are living and dead, and those who made Wyandotte their home, we further thank your organization for the honor you have done our city in showing their part in the iron and steel industry of this country. I thank you, your organization, your association, for this most fitting tribute."

President Gilligan: "We are particularly honored today in having with us William C. Kelly, the son of the William Kelly whom we honor."

William C. Kelly's Address

"Mr. President and gentlemen, members of the American Society for Steel Treating, Mr. Mayor, and particularly Mr. Robert Hunt, a gentleman of world-wide reputation, I need not tell this audience, looking upon that tablet, that I feel inspired as no other occasion could affect me. There are others, though, besides William Kelly whose names I feel should be on that tablet, though don't accept that suggestion as a criticism of the tablet, men like Capt. E. B. Ward. I don't believe that his best friends knew what he was doing, and if I may be permitted to take your time, ladies and gentlemen, I am going to tell you what he did before I get through. It would scarcely be worth while for me to take up any of the time of this large audience in going into any of the history of the bessemer process. Others more able than I have told that story. But there is a story which I would like to take advantage of this occasion to tell, that is unknown to the world, it is a part of the story of the bessemer process, which I should call the pneumatic process. It is intwined with romance and tragedy, and I believe might be interesting to you. In as brief a way as possible I will tell you this story.

"William Kelly was in the dry goods business in Philadelphia, though he had made his lifelong study that of metallurgy. In those days the states throughout the country had their own individual financial and banking systems, every state had its banks; not all the banks put out their own money, and merchants in Philadelphia who were selling goods throughout the West had difficulties of collecting that we do not experience in these days. As a junior member of the firm of McShane & Kelly, he was sent out on a trip to collect the debts owing them in Western Pennsylvania, Tennessee, Kentucky and Indiana and Ohio, and when he had reached Nashville, Tenn., he was then through his trip. Now this large crowd of young ladies here suggest and inspire me to tell this story. When Mr. McCloud honored me with an invitation to be here, I didn't know exactly what the program was, and I have made no preparation to make any address, so what I have to say is only told you in a rambling manner. But as I look upon these young ladies here it reminds me of a romance connected with William Kelly's life which has never been told, and as a great believer in Providence, I think probably it had more to do with the discovery of the decarburizing of iron without the use of fuel than any one thing.

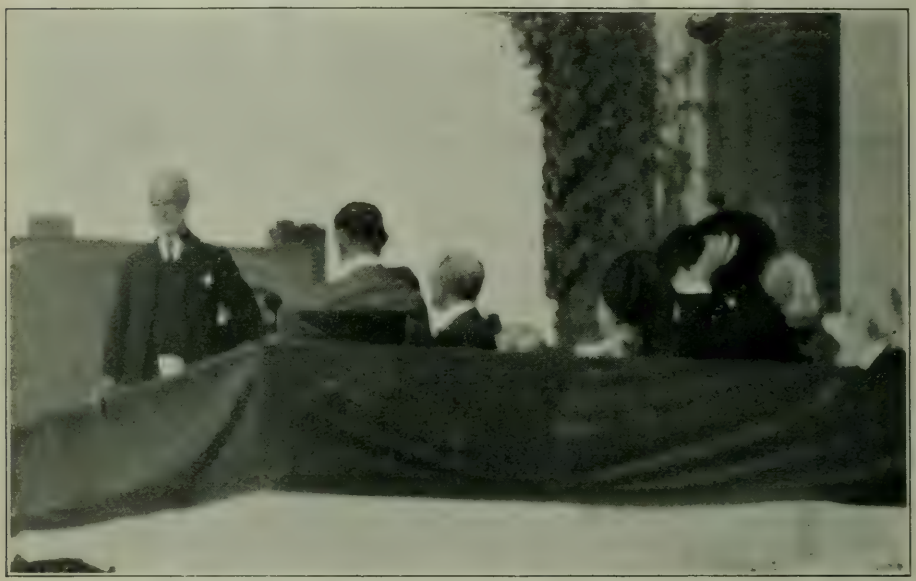
"After he had finished his business in Nashville, Tennessee, his friends wanted to entertain him, and the most interesting place to visit in Nashville, Tennessee was the female Academy. It happened to be the end of the school year and there was a graduating class marched out and placed on exhibition. Now William Kelly was considered an exceedingly handsome man, although none of his sons took after him, I am sorry to say. There were some 12 or 15 girls lined up, they were the graduating class, and in that crowd there was a little girl just sixteen years old, with her hair streaming down her back, and I presume she had on short dresses like you girls wear. Anyway it was a fateful moment for William Kelly. There she stood, an apparition of loveliness, and he had met his fate! I will not tell you the long story which usually follows such affairs. You all know more about that, and particularly you younger ladies, than I do. I have gotten so old I have forgotten that part of the story. But he procured letters of introduction from friends in Nashville to merchants in Eddyville, Ky. where he had learned the young lady lived, and he took the first steamboat to Eddyville. He found that a little town on the Cumberland River, a rather small place, 300 or 400 inhabitants, but it was a great market for tobacco, and one of the first gentlemen he met there was Mr. Gracey. Mr. Gracey lived part of his time in Eddyville and part of his time in New Orleans. He was a great tobacco merchant. He bought up all the tobacco around that country. Mr. Kelly took particular pains to get well acquainted with him and cultivate him because he expected to see that little girl coming down from Nashville in a few days, and he wanted to meet her again, and he wanted to be on the good side of her father. He spent some time there, and I understand he did a good deal of buggy riding around the country, and in the course of those rides, while I presume he was very much absorbed with the young lady, at the same time he took occasion to find that the whole face of the earth was covered with a rich hematite ore, and he got word to his brother John F. Kelly in Philadelphia, who came out hurriedly, and they bought up all the country around there and bought a blast furnace, the Cobb Furnace. Shortly afterward William Kelly was married to this young lady and settled there and built Sewanee Iron Works and Union Forge on the river.

"Now in those days they made iron with charcoal, they didn't use coke, and you can readily understand how, in a few years the timber was all cut out, so they had to go so far to get this timber that it became a losing proposition. And another thing that had a direct bearing on this process, the ore, the surface ore, had given out.

"Up to that time they could go along with a wagon and men and shovel it up from the ground into the wagon and take it to the furnace and melt it into metal. That had given out, and from a very prosperous beginning they began to lose money and bankruptcy was staring him in the face, principally on account of the ore and timber giving out. Now one day Mr. Kelly was passing along in front of the knobbling fires in the forge,—and these fires, understand, were operating by colored men, they were slaves. He noticed in one of the furnaces, that the charcoal which had previously been on the metal had all burned away, there was no fuel there, but air was being blown into the knobbling fire and the metal was boiling. He threw up his hands, he had been studying metallurgy, he know what oxygen and carbon mechanically combined meant, and he recognized that he had made a great discovery, that if brought into mechanical union, you would decarburize the metal and make it wrought iron, and he had made a great discovery.

"Now I feel somewhat embarrassed. This is the first time I have ever spoken except very privately, to anyone regarding the pneumatic process, and I do think that on this occasion there ought to be some truths told for the sake of history regardless of whom it may hurt, and I am going to do it, if you will just give me a few minutes. Although it was not my intention to make a speech here, I am going to tell you some truths about William Kelly and which he had requested to remain unrevealed during his lifetime.

"Captain Ward of this city, as you many of you know, especially you



William C. Kelly, Son of William Kelly, Delivering His Speech at Wyandotte

pioneers, had Mr. Durfee go to England. Henry Bessemer had brought out this pneumatic process, but Bessemer had never made any more of a success of it as a steel process than had William Kelly, who never did claim to have made a success of the process. All he ever claimed was he had discovered the operation of the run-out fire, though he had made claims as to what he could do if he had the opportunity. Mr. Durfee went to England. Bessemer had become enormously wealthy by the sale of rights to use his process for making steel.

"Now as a matter of fact, he had never made a success of it until Robert Mushet brought it to perfection. You gentlemen know all about Robert Mushet. I will not attempt to go into that in detail. But Mr. Durfee's mission to England was to see this process in operation and to buy the Mushet patent for the Kelly interests of this country, and when he came back to America the first thing he did was to visit my father at my home and in the course of conversation he pulled out a photograph and handed it to Mr. Kelly and he said, 'There is a photograph of Henry Bessemer.'

"Now let me tell you that during his experiments at Sewanee Iron Works there had suddenly come upon the ground two Englishmen. The Sewanee Iron Works was way back in the interior, practically in the wilderness. It

took three weeks to get from New York to Sewanee Iron Works, where you can now make it in eighteen hours.

"Now what brought those Englishmen to Sewanee Iron Works? Kelly & Company had agents in Cincinnati, Shreeves, Steele & Company. They were importers of steel and iron, and they were the agents of Kelly & Company. They had doubtless written over to England about Kelly's experiments and about his making run-out iron without the use of fuel. These Englishmen came upon the ground, one of them was a very intelligent man, and they stayed there some time and assisted Mr. Kelly in his experiments, trying to develop a process for making the iron, the pig metal into steel, for William Kelly had had this pneumatic process in operation at his forge for years before he ever attempted to take out any patent on it, he was trying to perfect it, which he never did, never claimed to have done, and trying to make a steel process out of it. When Durfee handed William Kelly this photograph he said, "Great God! Durfee, that is the man who helped me in my experiments at Sewanee.'

"Now William Kelly asked Durfee never to tell that, and I never knew it myself until a few years ago my mother told me of the incident that it was so humiliating to my father he didn't want it known that he had been duped, and whether he was mistaken in recognizing in that photograph that Bessemer was the man who had come over there secretly, under an assumed name and had learned and gotten his idea and took it back to England. Whether that is true or not, there were two Englishmen there, and when they left, they left at night, they didn't even say 'Good-bye.' They were traced up to New York and went directly back to England, and if it wasn't Henry Bessemer then,—well, I believe it was. And he believed it was, because there was no mistake about the face of Henry Bessemer, and I believe, as I stand here, that Henry Bessemer was the man that came to Eddyville, came to Sewanee, got that idea and went back and never carried it a bit further toward success than William Kelly; and the very way that he treated Robert Mushet, the man who made it a practical success, showed that he had a yellow streak in him.

"Now I am sorry to say that, but as I said in starting out, I intended to tell the truth, regardless of whom it might hurt. Everybody that knows the history of this case knows how ruthlessly Bessemer treated Mushet. It remained for Mushet to perfect the pneumatic converter and due credit should be given him. Mushet you know was an eminent metallurgist.

"Now I have taken up enough time, but all my life I have had the desire, if the opportunity ever came, to tell the truth about this thing. I could go along and tell you that when William Kelly discovered this thing, this method of blowing, it was called there Kelly's air blowing process, and people thought he was crazy. When he had first discovered this, the first thing he did was to go home and tell his wife, because she had heard his complaints for months that the timber was giving out and it was going to break him. When he went home one day and told her he had discovered how to run the run-out fires without the use of fuel, by simply blowing air through the metal, she thought he was crazy and she immediately dispatched their daughter to town to bring her father and mother and Dr. Higgins. But he was a chemist and he explained to them that oxygen and carbon produced fuel, and this operation took the carbon out of the metal and reduced it to wrought iron, and he wasn't crazy at all. And a few days ago, after having received an invitation to this meeting, I happened to pick up a little booklet written by Mr. Butler of Youngstown, and in his 'History of Fifty Years in Iron and

'Steel' he tells how William Kelly, who, financially broke, went into bankruptcy on account of the ore giving out at Sewanee Iron Works. William Kelly at the time was trying to interest the steel men, the iron men of this country to develop this process. He went to Mr. Todd, I believe, of Niles, Ohio, if my memory serves me correctly, told his story and tried to interest him, spent a day there, had dinner with Mr. Todd, but after he left, Mr. Butler says that Mr. Todd remarked, 'That man is crazy.' And I dare say at that time nearly every iron man that he told the story to thought he was crazy. There was no opportunity, there was no chance, not a shadow of a chance, for William Kelly unless he could have developed and made his process a success himself to make steel, to ever interest an American iron man in it, because in those days the iron men were not surrounded by intelligent, high grade metallurgists to tell them what they were doing, as they are today. There was only one metallurgist at that time in the whole United States, Otto Worth of Pittsburgh, and it took two weeks to get from Sewanee to Pittsburgh to consult him, and it never occurred to Mr. Kelly to consult him, he didn't think it was necessary.

"I feel very much honored in being here today, but please understand, Mr. President, that I am not taking any of this to myself whatever; but when I look at that name there I feel that when this great body of scientific men have taken up this question and have emblazoned there on that tablet, they have done William Kelly justice, they have perpetuated the fact that he was the first inventor, or, as he termed it, (as William Kelly was not an inventor and never called it an invention) a discovery, a scientific discovery."

At the conclusion of Mr. Kelly's address President Gilligan thanked the assembly for their kind interest and co-operation in these ceremonies and all adjourned.

WHAT IS THE MATTER WITH THE AMERICAN RAILROADS TODAY?

By F. H. Alfred

WHAT is the matter with the American railroads, you inquire. I counter with the query "Who is running the American railroads?" A few years ago the late Franklin K. Lane, upon his return from the International Railway Conference at Berne, Switzerland, said, "The conference established, beyond question, I think, the supremacy of the American railroads, from the standpoint of efficiency." This statement, from a student of American business, would indicate that from his viewpoint there was nothing wrong with the American railroads as compared with the railroads of other countries—and how else can we measure the efficiency of railroads except by comparing their operations with the operations of railroads of other countries. There was held in Washington last year, the great Disarmament Conference, having for its aim an economic rehabilitation of the governments of the world, and a readjustment of their relations, one with another—through the elimination of war and the waste connected therewith. The greatest economic waste in the operation of the railroads of this country is occasioned through the application of regulations of commissions, state and national. One thing responsible for the condition of the railroads that stands out most prominently is *over-regulation*. I shall endeavor to set forth, briefly, in what way our railroads are over-regulated:

1.—The Interstate Commerce Commission regulations
2.—Regulations through state commissions
3.—Transportation act, known as the Cummins-Esch act

Interstate Commerce Commission

The Interstate Commerce Commission came into existence under a law passed in 1887. In 1908 when authority to regulate rates came into the hands of the commission, the average freight rate in the United States was 7.59 mills per ton per mile. These rates were reduced constantly until approximately 25 per cent of the entire railroad mileage of the country was forced into receivership. The rates reached the lowest stage in 1916 when they were, for the country, 7.07 mills per ton per mile. If I may refer for a moment to the Pere Marquette, as I want particularly to bring out the rate situation in Michigan, when that road was forced into receivership in 1907, its average freight rates were 5.9 mills, against an average for all roads in the United States of 7.59 mills, the average rate for all other roads being 29 per cent greater than the rates of the Pere Marquette. This road was again forced into receivership in April, 1912, when its average freight rates were 5.79 mills, as against an average throughout the country of 7.44 mills, being 29 per cent less than the average for all railroads of the country. The rates in Michigan have been lower than the average rates throughout the country since 1901, notwithstanding the higher cost of fuel and the hazards of winter operation.

The railroad executives in Michigan were successful, in 1917, in having this rate matter investigated by the Interstate Commerce Com-

A speech presented at the annual banquet of the Society in Detroit, October 5, 1922. The speaker, F. H. Alfred, is president of the Pere Marquette Railroad.

mission, as well as by the state commission, and as a result of the investigation, the Michigan zone rates were established. This zoning of the Lower Peninsula had the effect of bringing Michigan roads up to the average for the country as a whole. The result was most beneficial to the public, as well as to the railroads, for the Pere Marquette alone put back into its property over four times as much as the amount received from the increase in rates due to the zoning plan. The traffic representatives of the cities in our state, whose duties are to protect the manufacturing interests in their respective locations, have not been satisfied under the zone plan because of some increases brought about through this plan. They have been active before the Public Utilities Commission in repeated efforts again to break down our rates, which if successful, will, of course, result again in the breaking down of the transportation system in the state. The Michigan commission, in the summer of 1922, arbitrarily reduced the rates, intrastate, on sand, gravel, sugar beets and other commodities, making the rates on some of these commodities as low as the rates were in prewar times, notwithstanding that our costs of operation have not been correspondingly reduced. At a hearing before the Michigan commission in June, this year, I appeared and testified to the effect that the smaller railroads in Michigan were on the way and would soon arrive at bankruptcy. During the last year there were but two railroads in Michigan that made anything like a satisfactory showing in operation. One of the smaller roads, consisting of about 300 miles, went into receivership last year, and on Saturday last, another railroad, with mileage of about 100 miles, succumbed to the inevitable and asked our courts for a receiver. Another railroad, somewhat smaller, should be in the hands of a receiver at this time, and doubtless will be very soon. Unless some relief is afforded, other of the small railroads in the state will be forced into a similar situation. The members of our Utilities Commission should be, and doubtless are, students of economics, and they know as well as the railroad executives, the situation that confronts us.

The measure of success of railroads is dependent upon the three elements—rates, wages, and volume of business. Rates are in the hands of the commission, state and national. Wages are under the control of the Labor Board (except on small railroads under 100 miles in length). This leaves only, in the hands of the management, the volume of business, as a rudder to steer its course between Scylla and Charybdis.

Does the Interstate Commerce Commission's authority end with the rates, you inquire, or does that body have other authority over the operation of railroads? The commission has established a most elaborate system of reports and accounts. The law provides for all accounting to be kept under the requirements of the commission. Slason Thompson, Director of the Bureau of Railway News and Statistics, says the storerooms of the Interstate Commerce Commission are bursting with detailed reports for which it has no use. He has addressed the commission on the subject of "Waste in Clerical Service of the Railroads by reason of Accounting Requirements of the Commission." He shows that the number of clerks on railroads have increased in the past twenty-five years, 441 per cent as against an increase in all other railway em-

ployment of 137 per cent, the increase in clerks being three times as great as that of all other employes. He shows that if the commission will cut its statistical requirements one-third, it will save the railroads approximately $100,000,000, annually, and reduce the expenses of the commission by at least half a million dollars. Think of being able to save $100,000,000 per annum, which was 16 per cent of the net operating income of railroads of the country, on one item of accounting and still be able to function properly and furnish the commission with all the data that it should need. This amount of $100,000,000 per annum would buy fifty per cent of all the new box cars needed annually by all of the railroads of this country.

Does the authority of the Interstate Commerce Commission as applied to the operation of railroads, end here, you inquire. It does not. The commission, through a transportation officer, supervises, in a perfunctory manner, the physical operation of railroads. In times of stress, when one section of the country may suffer unduly by reason of shortage of equipment, or when there is danger of loss or suffering as in the handling of grain from the Northwest or fuel from the mining regions, the commission is empowered to take direct control of the situation.

Transportation is an evolution, perfected through continued operation, and cannot be disrupted as has been and is being done, without seriously impairing the service.

In every department of human affairs, practice long precedes science. Practice comes first in every new enterprise. Development, through scientific study, follows. Our understanding of economics is undergoing progressive development resulting from highly competitive business conditions. If there were no competition there would be little or no development.

With reference to the abandonment of unproductive lines. No line of railroad can be abandoned without the approval of the commission. It matters not how unimportant, or unnecessary, or how expensive the service may be, the operations must continue day after day until authority can be secured to discontinue. I consider this good practice and do not question the justice in the matter but securing the approval of the commission, even after the presentation of ample proofs, has been most difficult. I cite the case of a branch line on this railroad, six miles in length, running from Elmdale into the small village of Freeport. Six miles of branch line is a small piece of railroad to operate, particularly where there is no business. To require a service, six miles in length, to meet the passenger service on main lines, in this modern day with the automobile in such general use, and at a loss of $67,222 in two years and a half, equal to approximately $27,000 per year, or $4500 per mile, is wholly unwarranted. We are compelled to operate this line and to bear this continuing loss. Passenger traffic on the Pere Marquette railway, moving less than 25 miles, has decreased eighty per cent since 1916.

The Detroit Times, in commenting on the request of the Pennsylvania railroad to discontinue the service on the Barnegat Line, states that this explains the difference between public and private ownership; that public ownership considers the public needs—private

ownership, the stockholders dividends. The Post Office is owned by the public. How would it seem if private individuals owned it and discontinued all post offices in out of the way places that don't pay expenses? This is a very fair statement but does not go far enough. In the case of the Freeport Branch, if the people living at Freeport can be provided with a service that will take care of the needs of that community without assessing upon the business of the state $27,000 per year, it would seem that it should be done. The people must be educated to the fact that every unnecessary expense of a publicly controlled business (and without doubt railroads are wholly controlled by the government) must be paid out of the public pocketbook in one form or another. It is a misstatement to say that the money saved from this operation would go in dividends to the shareholders if the earnings exceeded 5½ per cent on the value of the property.

I have only referred to some of the powers of the commission as it affects the operation of railroads.

State Commissions

In discussing the Interstate Commerce Commission regulations, I have made specific mention of regulations through state commissions, and will therefore not go into detail as to the powers of this body.

Transportation Act—Known as Cummins-Esch Act

Under this act, which became effective on March 1, 1920, the Interstate Commerce Commission is charged with the duty of providing a system of rates that will yield a net return of 5½ per cent on the valuation of railroad properties as a whole, or in groups, as arbitrarily determined by the commission. There is no guaranty, but there is an inhibition against the possibility of earning more than 5½ per cent on a government valuation of railroad property. If any individual railroad does not earn 5½ per cent, it has no recourse under the law, but if it does earn more than 5½ per cent, one-half of the excess, under the provisions of this law, becomes the property of the government.

This act also provides for the creation of a Labor Board, the duty of which is to fix the rates of wages, rules, and working conditions, and adjust grievances that arise between the employes and the management. In adjusting the dispute between the management and the shop crafts, the Labor Board has been wholly unsuccessful. The shop crafts had accepted all favorable decisions of the Labor Board but refused to accept the decision of the board under which the wages were to be reduced 10 per cent, effective July 1, 1922, and declared a strike as of that date. The Labor Board called before it, at its headquarters in Chicago, on June 30th last, the executives of the railroads and grand officers of the shop crafts, in an endeavor to avert the threatened strike. The shop crafts were adamant in their refusal to abide by the decision of the board—the president of their combined organizations refused to appear before the board and refused to obey the board. On July 8th, the Labor Board adopted the following resolution:

"It must be conceded that the men who remain in the service, and those who enter it anew, are within their rights in accepting such employment; that they are not strikebreakers seeking to impose the arbitrary will of an employer on employes; that they have the moral, as well

as the legal right, to engage in such service of the American public to avoid interruption of indispensable railway transportation and that they are entitled to the protection of every department and branch of the government, state and national."

And on July 12, President Harding, in his proclamation, said:

"The maintained operation of the railways in interstate commerce and the transportation of the United States mails have necessitated the employment of men who choose to accept employment on the terms of the decision (of the Labor Board) and who have the same indisputable right to work that others have to decline work.

"Wherefore I am resolved to use all the powers of the government to maintain transportation and sustain the right of men to work."

Notwithstanding the firm stand taken by the Labor Board, and by the President the strike of the shop crafts has continued, with acts of violence and destruction of property which have made it necessary for the government to procure the issue of an injunction to protect the interests of the public in thus assuring continuous railroad operation. Further, notwithstanding this firm stand referred to, suggestions were made to the management of the various roads, by the President, that they take back all of the strikers except those guilty of destruction of property and personal violence, and give to them their seniority rights which they would have enjoyed had they not quit the service of the railroads. This the railroad managements refused to do by almost a unanimous vote, taking the position that they must of necessity protect the old men who remained loyal and the new men who came into the service after July 1st. The other labor unions, particularly the Big Four, composed of the men in train, engine, and switching service, undertook to bring pressure to bear upon the management to cause the return of these strikers with their full seniority rights. As a matter of fact, a number of roads have made compromise settlements with the shop crafts, under what is known as the Willard-Jewell agreement, whereby all the strikers are to be taken back into the service before October 15th, 1922. Some roads, on which few of the old men remained loyally in the service and where few men were hired, felt that they were warranted in settling under this compromise arrangement, whereas other roads, on which more of the old men remained loyally in the service and where large numbers of new men were employed under the guaranty of the management that they could be continued in the service as long as they complied with the rules and regulations, were not in a position to take on all of the strikers and have refused to do so. The sum of the loyal men in the service and of the new men that came into the service, together with the men who went out on strike, would increase the forces of the railroads in the country by over 100,000, or 25 per cent more than are normally employed in these departments. We do not feel we were warranted, in the first place, in sacrificing the principle that had been supported by the President and the Labor Board, and in the second place, in wasting money which should be employed in the betterment of service to the public.

Summary of Over-Regulations

The impression seems to prevail quite generally that railroads are

now under private control, whereas, as a matter of fact, the railroad companies and their operations are, and have been, under public control for many years past. By public control I mean that control which, through regulation, has been placed in the state and federal commissions and in the United States Labor Board. In all important essentials, this control through public authority is, as stated, practically complete.

It covers:

A. The fixing of the carrier's rates for service through which its revenues are derived

B. The kind and character of equipment that shall be employed

C. The wages, rules, and working conditions of employes, for employes have only to disagree with the carriers as to such matters in order to obtain public control thereof

D. The financing of the carrier through the control of the issuance of securities

E. The accounting methods of the carriers

F. The terms of contract for transportation between the carriers and the shippers

G. Grade separations; train schedules; the use of terminals; the leasing of lands; the purchase, construction, sale or abandonment of tracks, etc.

All of the important incidents pertaining to the service of a railroad company which relate to the method of handling its property, or to the receipt or disbursement of its funds, are subject to state of federal regulatory and restrictive laws and orders, or both, which are often conflicting, and in the these conflicting orders, laws and regulations lie, to a great extent, the bane of the present system of public control. The average railroad official would not object to complete public control of the public service which his company performs, if the governing body, whether it be the Interstate Commerce Commission or any other organization, were required to carry the responsibility of such control and thereby to become answerable for the results thereof. Every railroad company has two great obligations to fulfill—first, its obligation to the general public in the performance of its service; second, its obligation to discharge its financial debts. As to the second obligation, it ought to be clear to any one that unless a railroad company is permitted to earn the necessary funds for the improvement of its service and for the discharge for its financial obligations and thus to maintain its credit, that the first mentioned service obligation will necessarily fail. The obstacles which now confront the railroads in their vain attempt to give the service which the public demands, are largely caused by the failure of congress and of the state legislatures, the federal and state commissions, in not co-ordinating their efforts, first of all, in the promulgation of a plan which will render railroad credit, at all times, stable and secure, so that by the use thereof, the demands which they are constantly making can be reasonably met. Instead of such co-operation, we find antagonism between the laws and regulations of the state and federal governments and often

between the states in their respective fields of control. For illustration, the Federal Valuation Bureau has undertaken to place a value upon the property of the railroads and under the transportation act the Interstate Commerce Commission is charged, for the first time, with the duty of providing a system of rates that will yield a net return of 5½ per cent on the aggregate valuation of railroads, which have been grouped for the purpose. The provision referred to, however, is unfortunately ineffectual and the efforts of the Interstate Commerce Commission to render it effective, are completely blocked by reason of certain other provisions of the transportation act which restored to the states, after September 1st, 1920, the power to charge intra-state rates. The states are now therefore attacking the rate schedules in effect prior to September 1st, 1920, without reference to the effect that the reduction of intra-state rates will have upon the fixed return of the carriers, without taking into consideration the value of the property dedicated to railroad service, and with a certain knowledge that such reduction will result in preventing the Interstate Commerce Commission from putting into effect, general schedules to insure the fixed return and to thereby aid the carriers in financing their present requirements.

Impossible to Operate Industrials Under Railroad Restrictions

Conceive Mr. Ford, in the operation of his interests, having the sale price of each automobile, truck and tractor manufactured by him, fixed by a government agency; that Mr. Ford had no power to increase this price regardless of the cost to him in producing the same; also assume that his plant must be kept continuously in operation without reference as to whether such operations are conducted at a profit or loss. Let us further suppose that a Government agency has fixed the rate of wages that shall be paid to every class of employee, and has established 186 shop rules and working conditions under which a mechanic, apprentice or helper would not be permitted to perform any service except as prescribed by the labor organization to which that individual belongs. Imagine further, if you can, that he is required to ship and market cars in a territory where they are not needed or used to any great extent, and where the people in the particular locality cannot afford to own, and do not pay for them, and that public authority had regulated his business with the intention that the loss on such cars must be borne by those who are purchasing his product in other portions of the country. Further let us assume that a government agency had determined that he shall not be permitted to earn more than 5½ per cent per annum, not upon the capital which he has wisely, economically, and honestly invested in his business, but upon an arbitrary valuation of his physical property, based on the findings of a group of men, many of whom may be classified as clerks, who have had no experience in the construction of large industrial plants, or personal knowledge of the cost thereof, and whose investigations and findings must necessarily, in large part, be based upon hearsay. Consider further that he is given no assurance, other than the broad statement in the law that the intention is to so fix the selling price of his cars, taken as a whole, that he will receive 5½ per cent upon this indirect, arbitary and unscientific method of valuation of his property; that if such 5½ per cent is not earned in any one year, it is his loss—

a loss which cannot be recouped under the provisions of the law, in subsequent years; that if he earns, by chance, more than 5½ per cent one-half of such excess must be turned over absolutely to the government, as its property, which amount would in turn be loaned by the government to his competitors in business, upon terms satisfactory to the government, and provided that they could furnish the necessary collateral security. Under such a condition of regulation, Mr. Ford's plant never would, and never could have been constructed, and if such regulations had become effective after the development of his plant, he could not continue his business with success, and this I say with all due respect to Mr. Ford, and in full recognition of the fact that he is a genius in business organization.

Let us now return to the railroad situation. The transportation act does provide that railroads as a whole, or in groups, shall be permitted to earn 5½ per cent, not on their invested capital, but on an arbitrary valuation of their entire physical property, fixed on findings made by a group of Government representatives, and tariffs have been established that would permit of this under normal conditions, yet, as a matter of fact, the railroads have not earned 5½ per cent on the valuation as fixed by the Government representatives, since the enactment of the law. The law became operative March 1st, 1920, upon the return of the railroads to the owners by the government. They actually earned, during the 10 months of 1920, 0.312 per cent; for the year 1921, 3.3 per cent, and for the first 7 months of 1922, 4.36 per cent, so that the railroads have not been able to earn, under the regulations of the Interstate Commerce Commission and the Labor Board, one fixing traffic rates and the other the wages of the men, 5½ per cent on the government's valuation of the property. This is only one of the regulations, but I believe you will agree with me that it would be unnecessary for me to mention any other. However, I must, at this time draw to your attention, other regulations which, while not as serious as the one mentioned, are exceedingly burdensome.

Relation of Employer to Employe

No particular qualification seems to be necessary to admit men in every walk of life to assert, with authority, their views on the pros and cons of unionized labor. If unionized labor in its present form is a good thing for the country, why is it that it is gaining strength only in public and quasi-public controlled industry where competition is not keen? Why is it that the great majority of the privately owned industries maintain an open shop? My theory is that the laws regulating the relations between the railroad and its employes should be repealed and that the only exactions put upon the railroad in connection with the handling of its labor, should be the necessary protection to insure safe, sanitary and humane conditions. The wages should be regulated entirely by the law of supply and demand, just as they are regulated in other lines of industry, and should be in line with the rates paid by other lines of industry in the same territory, for the same class of employment. I think no one would deny the right of labor to organize to protect itself to this extent and it should be the duty of the public to see such regulation is provided that will secure to every working man surroundings that are safe, sanitary and humane.

Under the union plan it is the job that is unionized and not the ability or worth of the man. A standard day's work is established that overpays the incompetent and makes a sluggard of the adroit worker. No one can establish a competence who does not make a conscientious effort.

Under our Constitution all men are born equal but they do not continue equal. Bishop Thomas Nicholson of Chicago said—"The wage worker will never be satisfied with higher wages and shorter hours any more than you or I will be satisfied with more profits and a better house. Things never did satisfy anyone, and never will. Satisfaction and contentment are matters of religion. Communities and industries, where motives are paramount, have no serious troubles." There is no solution for unemployment except by increased production and yet the unions are keeping their members, and others, from work by the thousands, all over our fair land. The worker is completely under the domination of his union, to the dwarfing of his own opportunity. Alexander Hamilton said—"Give all power to the many and they will oppress the few; give all power to the few and they will oppress the many. Both, therefore, ought to have the power that each may defend itself against the other."

The McAdoo administration of railroads will be recorded as the most costly and destructive agency, resulting in the greatest tax burden that has been inflicted upon the people of the United States since the Civil War. The heritage of the railroad owners, as a result of government control, is a 100 per cent unionized plant, with esprit de corps of employes at zero. The system of public control now in effect is ridiculous, indefensible impossible. The hands of railroad managers are bound. Unless congress takes up this serious situation and furnishes the relief which it alone apparently has power to grant, federal operation must again be undertaken and the tax payers of the country will bear its burdens.

Remedy

The old school management must succumb to new methods and men with power to incorporate into transportation the most modern business methods. Steam railroads have been the forerunners of civilization in this country and in Canada. Great courage was manifested by the men who extended the ribbons of steel across the plains and through the Rockies, in advance of requirement from a commercial view point. The rails of some of these roads are not yet filled with traffic. Have the arteries in the East expanded with the necessary rapidity in providing additional main tracks and terminals to handle, at all times, the seasonal business of the country? If not, have provisions been made to warehouse business that could not be moved to furnish protection to the producer? My heart goes out to the fruit grower and farmer, who is obliged to sell his product on a glutted market which always means a lower price, because no provision is made for warehousing. Why should the railroads not receive encouragement, through rates, to provide warehouses for storing grain and produce and pre-cooling stations for storing fruit, and allow the shipper the use of these facilities for a charge to cover interest on investment and upkeep? This would help to avoid congestions that occur annually on railroads, and at the

same time save the farmer many a heartache. Why do railroads not prevail on wholesalers to locate on the tracks of the company, where goods can be unloaded and re-shipments made in the same cars? If we have laws that will not permit of practices in the interest of the farmers, fruit growers, etc., then it is our duty to help to secure such modification as will permit of these vital economies. To my personal knowledge, there have been blockades on railroads, making embargoes necessary every fall, for the last twenty years. The same thing occurs year after year and nothing done to remedy the situation.

The improvement in steam locomotives have been practically nil during the last decade. Changes were made from the slide valve to the piston valve a few years ago and it is now a question as to whether the slide valve is not a better valve than the piston except for the fact that superheat could not be applied with the slide valve. The Walschearet gear that was applied to our locomotives a few years ago, was patented about 1850. We continue to weld flues in about the same old way and with the result that leaky engines are constantly with us. The automobile men have, in twenty years, developed a machine that seems to be about as simple, fool-proof and perfect as man need want. Why cannot the railroads more nearly perfect their equipment? About the only change we have made in passenger coaches is to double the car weight per passenger by building battleship coaches. If we would set about to overcome the journal friction, a saving worth while could be made in the cost of operation.

The reason for this situation is that the railroad managers have, in consequence of the numerous heavy penalties required by law, been obliged to give first attention to the numberless restrictive regulations of the public governing bodies,—the state and federal commissions.

Marked improvement is also possible through a revision of union rules that will eliminate 90 per cent of them. The same old stuff is incorporated in rules year after year, never taking out but always adding to, until some of the rules are, in themselves, so confusing that even the ones responsible for them cannot interpret them. I recall having given six months continuous time to making new schedules with employes of one railroad.

Why were the commissions given so much power? Judge Cooley, in his first report as Chairman of the Interstate Commerce Commission said:

"This act to regulate commerce was not passed to injure any interests, but to conserve and protect them. It had for its object, the regulation of a vast business according to the requirements of justice."

Under the Act of 1920, the duties of the commission were to conserve and protect the resources of railways that they may provide the service required by the public. If the Interstate Commerce Commission could function under the interpretation of its duties as outlined by Judge Cooley, the first chairman of the commission, it would seem the railroad situation would clear itself. Railroads have continued to function and improve in spite of the opposition of the general public. The performance of the railroads in handling the present volume of business, which is as great as has ever been handled in the history of the

(*Continued on page* 238)

THAT MIND OF YOURS

By Marion L. Burton

TONIGHT I am going to speak upon something which concerns every person in the room, a subject of which every one of you, I believe, has a part, however small it may be, and in regard to which, if you have the faintest glimmer of intelligence, every one of you ought to have some convictions. It is a subject which is just wrapped and shrouded in mystery and that is the reason I can talk about it so long. But, nevertheless, it is a subject in regard to which there is something that is very important for men and women, it bears more specifically upon your personal success, probably, than any other single factor with which you deal, it has more to do with the efficiency of your shop, or of your office, or of your corporation, than anything that I could discuss tonight—it is more profoundly important for the administration of every municipality and for the administration of the government of the United States than anything with which I could deal, and it is absolutely and unqualifiedly inevitable if we are to solve some of the problems which confront mankind and civilization at the present hour.

The subject upon which I want to speak is—*That Mind of Yours.*

I said to you that the whole thing is wrapped and shrouded in mystery. I wish there were time tonight for me to discuss with you very briefly what might be called the Emergence of the Human Mind. I might begin by telling you that probably in the first croakings of the frogs we had the first glimpse of mental intelligence. I wish there was time to trace it from the amoebas and the frogs, the fishes and the birds clear up to the monkeys and ourselves, but there isn't time to do that tonight. I wish there were time just to illustrate to you where we come to the point, possibly, where there is the dawn of reason in this marvelously fascinating and evolving thing we call animal life.

I wish I could tell you about a creature over in the zoo in London so much like some college students that it is almost impossible for me to think she hasn't been registered in some of our American institutions of higher learning. She goes by the name of Sally. The teacher was trying to see if Sally could learn how to count and he would say to Sally, "Sally, give me two straws." And Sally would pick up a straw and put it in her mouth, and then she would pick up a second straw and put in her mouth and hand the two straws to the teacher. Then the teacher would say, "Now, Sally, I want five straws." And Sally would go through the same process and would give him five straws. But, like the average mind of the average undergraduate in American colleges and universities, if there was any attempt made to go above five straws, Sally didn't like it. And if you asked for six or seven or ten straws, she would take a straw and bend it so two ends would show instead of one, and thereby attempt to get away with the proposition. To me there is nothing quite so fascinating besides American public audiences as a cage fully of monkeys. When you think of their restlessness, their inquisitiveness, have you ever watched cages of monkeys, have you ever seen how they are alert every minute to take in what is going on in their environment? How they are never satisfied with the experiments they have made, but are constantly investigating one another and the universe of which they are a part? Have you ever stopped to think

---

A speech presented at the annual banquet of the Society in Detroit, October 5, 1922. The speaker, Dr. Marion L. Burton, is president of the University of Michigan, Ann Arbor, Michigan.

that in that fascinating little animal we have a hint that there is something finer and better, after all, to come out of this animal kingdom than we have yet seen.

They tell the story of a polar bear, I don't know where he was, it doesn't make any difference, but they used to throw buns to him and he would jump into the water and swim over and get the bun in his mouth. But finally they threw so many of them he didn't have time to swim after each individual bun, but he learned that if he would stay on the rock and take his paw and scoop the water like that (illustrating) it would cause little waves on the water and make the bun float over to him. I wish we could all get up to that high type of intelligence—*That Mind of Yours.*

And now there is just one other thing I want to say before I begin—there may be in this room tonight some of you who have studied the newer problems of psychology and of psycho-analysis. Some of you may be thinking a good deal these days about the whole problem of the unconscious element in our minds. I suppose the best psychologists today would concede that in these things of ours that we call minds there are at least three distinct layers. The mind doesn't dwell in any place, but there is that that might be called the upper layer, that you and I are perfectly conscious of. Those of you who are awake now are conscious of the fellow with red hair who is trying to make a speech to you. That represents the upper layer. Suppose I should stop and say, "Who was President of the United States before Mr. Harding?" After a time somebody would say, "I recall who it was." That represents another layer in your mind. That is the thing that is available. Somebody can ask you a question of something that you hadn't thought of for thirty, forty or fifty years possibly, and you could say after a while "Why, yes, this is it."

Then way back below that the sub-conscious, the layer or element which recent psychological discoveries have proven, probably has more to do with our conscious behavior than any other part of our mind.

Now I hope I have just given you a hint that the whole problem of the mind is shrouded and wrapped in mystery, yet an island of certainty upon which you and I can stand and which demands of us, if we lay claim to the high and royal prerogative of American citizenship, to see to it that that mind of yours is just as fine and splendid as it is possible for you to make it.

The Primacy of the Mind

Having said that, maybe I will begin. The first point that I want to get to you is this: you won't like the word, I don't like it, but I have not been able to find a better word—I want very briefly to get to you this point of view with regard to this subject, *That Mind of Yours.* First of all, I want to get to you what I call the Primacy of the Mind, the *Primacy of The Mind.* You say, "What do you mean by that?" Well, I mean the unqualified importance of the mind. I mean its significance for everything that you and I do. Now if there were a lot of time tonight I think I could demonstrate to you that the mind is the one thing which, above all else, conditions your own personal success. There are men in this room tonight who think that success is not conditioned upon brain power, who think it is determined by luck or by friendship, or by personal pull, or by large amounts of money; but let me say to you this, that beyond any fear of successful contradiction I believe that human progress has been largely

mental progress, and every time you find for me a man with a brain, stored with facts, capable of thinking about the relationship of those facts, that there is a man who will have a first class opportunity to make his contribution to the solution of the problems of his generation. A man with a mind counts today anywhere in the world, and there never has been a generation when he has counted quite so much as the generation in which you and I have been given to live. That is one thing. Knowledge is power. Socrates was right. Now don't misunderstand me—I don't mean to say it is the whole thing. I am perfectly well aware of the fact that mere theorizing, simple ratiocination, mere intellectualism, doesn't always get you very far. But what I am trying to say is that it lies at the basis of the thing, and that along with that mind, if yours is the kind of thing it ought to be—if you have even the facility for developing a short circuit now and then and getting a little of the human quality into your relationships, you are almost irresistible in dealing with the unprecedented problems of this generation.

You see what I mean. We must reckon on the other things that we call the human element to make the mind what it ought to be. But a man who is mere good nature, simply the personification of good will, who thinks that by diplomacy alone he can do the task, is unwise, for we are only going to arrive at the solution of the problem with clear headed people working to sound conclusions, based upon indisputable facts, based upon our problems. The man who expects to succeed in any task today, in your factory, in your office, in your organization, any man, anywhere, must first of all get something to going on right up here. When you do that you have gotten into the most fascinating thing there is about life.

I wonder how many of you ever heard the story of the three pigs down in Texas.

These three pigs, little brother pigs, were born down in the state of Texas. And you can find this recorded in one of the scientific experiment bulletins of the state of Texas for the year 1916. They decided to make an experiment upon these three brother pigs and they named them Tom, Dick and Harry. They put Tom in a pen and gave Tom a scientifically balanced diet, containing just the proper amount of carbohydrates, proteids, fats guaranteed to satisfy the palate of the most fastidious pig, and they said to Tom, "We beg of you to partake of this diet, ad libitum, ad infinitum, ad nauseam. The result of this part of the experiment was that at the end of six months Tom had gained 94 pounds and he was not worth as much in the open market as was the food he had eaten.

They took Dick, put him in the same kind of a pen, gave him the same balanced diet, followed the same directions all the way through as they had with Tom, with this exception, they gave him some alfalfa which he was permitted to nose and eat, and at the end of the same six months he had gained 200 pounds, and he was worth a great deal more in the open market than the food he had consumed in that interval.

Then they took Harry, put him in the same kind of a pen, with the same kind of a diet, plus the alfalfa, plus an open gate through which Harry was permitted to enter a pasture and to roam and to root as he saw fit, and at the end of the same six months Harry had gained 312 pounds.

QUERY: Is education something that you hand down, or dig up? You

have a right to occupy some spot on the earth just in proportion that you have something going on up here. The only way you can learn anything is with an active mind. Queer sort of a conclusion isn't it?

Now I am trying to say something about the primacy of the mind. Do I need to repeat here what you have heard so often, and which you can never hear too frequently? Namely, upon a high level of intelligence depends the future of this American Democracy, and if America is to realize upon her invested hopes and aspirations, it must be because she has an intelligent citizenship. Intellectual incompetency may be satisfactory for Russia, but I beg of you to remember that if America is to win in her great experiment of Democracy, she can only do it because that mind of hers is what it ought to be.

And there is another thing. If there were time tonight to sketch the history of the last three hundred years with regard to human progress, I think you could agree with me speedily that human progress everywhere has always waited upon science, upon discovery, and if you and I are to be worthy of our generation, as men have been worthy of theirs in the past, we must see to it that this world of ours is mastered, and that the human race escapes from old tyrannies and new, because men with minds, day by day, and hour by hour, are seeing to it that the unsolved problems of mankind have brought to bear upon them that intelligence and mental power which will solve them. Yes, progress waits for it. And as I have already hinted twice, there never has been a time when there was such demand for mind power as there is at the present moment. The world today is just bristling with opportunities for the man who can think, for the man who knows, for the man who has some comprehension of what this marvelous, fascinating thing is that we call life. Do you see? And if there were time I would discuss these problems with you just briefly, not for the purpose of solving them, but merely by way of illustration. You know the natural sciences, in the last half century particularly, have put to shame all the other departments of learning, but we have come now to the point where all the social sciences, like economics and government, psychology, anthropology, all the sciences that deal with civilization and man, and some adequate comprehension of where man is going, these too must come forward with similar conclusions.

I wish I had the time tonight to discuss the relationships of capital and labor and some of the problems that President Alfred of the Pere Marquette has referred to tonight with his experience. I wish I could discuss with you what, to my mind, is probably the most vital problem before this generation, namely, our relationship to the rest of the world. You know if we are going to get back to normalcy, if we are going really to establish financial prosperity in this country, have an international trade that will get us anywhere, sooner or later we must come to recognize that the future of America depends upon the peace and the future of Europe, Central Europe and the East, and all the rest of the world. Whether we like it or are aware of it or are prepared for it or not, the fact remains America can never realize her ideals or come back to that period of general prosperity and stability which we all crave at this hour until in some way we get ourselves related in the right way to the rest of the world. Now I am not talking about a league of nations, I am not talking about an association of nations, I am not talking about this or that particular solution, although I would if there were time; but I am absolutely sure of one thing, that anybody who understands what

has happened to civilization and to Europe in the last six or seven years realizes, with the possible single exception of the British Empire there is not a solvent nation in Europe today. France is spending twice what she receives, Italy is tripling her budget, even Holland and Switzerland and Sweden have gone beyond their budgets. When you think of the disruption of transportation and the breaking up of manufacturing, the millions and millions of people that are living in chaos today, then I say to you there is no possibility of our getting back to normalcy until America assumes her normal obligations to the rest of mankind.

And I go North and South, East and West, all over this country, and I think I have a certain facility for finding out what men are thinking, and I am perfectly sure of one thing, and that is this, that America is ready now to accept her normal obligations to the rest of the world.

Now having said all of this only by way of hint to have you see the problems with which we are dealing, and therefore the inescapable necessity for what I have called that mind of yours, the primacy of mind—if you can get intelligence into yourself, into your office, into your organization, think of the problems that you can solve and of the contribution you can make to the prosperity of the United States of America.

The Receptive Mind

My second main point is this: If we are going to think about that mind of yours, it may be helpful and interesting to think for just a moment about various types of minds. Again I wish I had an hour just to discuss these things, but I will just hint at them. As I do, just try to practice some introspection, without becoming too morbid. Try to decide, if you have one, what kind of a one you have. Now I wonder how many of you have read enough of philosophy to remember there was once a man who spoke of the mind as a *tabula rasa*, that is to say, just a plain, blank tablet, upon which things could be written. I am of the impression that multitudes of persons have just that type of mind, a thing upon which anybody can write anything. When I studied biology I used to poke the back leg of a frog and it would kick like that (illustrating) just when you poked it. There are multitudes of people who respond instantaneously to every external stimulus, they swallow it whole and never even have intellectual indigestion. They are the people who are so credulous, they are the people who make it possible for other people to say such absurd things, that would be so if they were true. They are particularly expert in the acceptance of all kinds of rumors, and the less likely the thing is to be true, the more glibly they take it in. You know them. I sometimes think this is one of the curses of America, that you can say some things which obviously are impossible, and yet some people will believe them, they are so receptive and credulous that anything that you write on the tablet of their minds just goes right down in and is received with a great and hearty welcome. Have you that kind of a mind? If so, you are not a citizen.

The Independent Mind

Then there is another type, the man who has a mind of his own, he is interested, he knows how to listen, he knows how to weigh evidence; more than that, when he listens he doesn't pay so much attention to what people say as to what they mean. Now you men who are executives and presidents,

you know what I mean. I don't pay so much attention to what a man says when he comes into my office, I am particularly interested in what he says without knowing he said it.

Do you know they tell of Herbert Spencer, this incident—when a new book was presented to him he would always approach it with the cold, intellectual question, "Is it true?" I am not minimizing that ideal, mark you, in fact, I am in a way talking about it. But they say of Maurice, the founder of the broad church party, that when a new line of thought was presented to him, he always asked this question, "What does it mean?" That is what you and I must do with regard to some of the things that are being said about us, and all the organizations and agencies that make up what we call our government, we must listen and weigh evidence, but we must have minds of our own in interpreting the evidence. We must be able to take these things and think them through. A man is not an encyclopedia, you can never make a life by a haphazard, ill-considered jumbling of everything that life, in its richness, is trying to hurl at you. No. A man thinks, he weighs evidence, he sees the relationship of these things, he comes to conclusions independently. Here are two types of minds. Which kind have you, the receptive, or the independent?

The Conservative Mind

Take another contrast, there is the conservative, the man who has the defect of imagining that truth knows time distinctions, that is to say, that a thing is true because it is old or new. He has the defect, too, of idealizing too much the past, but he has the merit of capitalizing his experience or believing in a stabilized, continuous world.

The Radical Mind

Then there is the radical. It is awfully dangerous to speak about a radical today, because he has so many different shades of red and pink. Some of them sit with torses that are trimmed in red and blue and pink, and think they think they think. They disrespect the past. They have the fatal facility of identifying realities and truth with the changing terminologies of differing generations.

On the other hand, the radical has been of real benefit to us. He has idealized the future, even though he may neglect the plain duties of the present. More than that, he has sometimes been identified with progress. So we want to be very sure we catch his truth and that we attack his error. You here—which are you, are you the conservative, or are you the radical? When I talk to students I always like to poke a little fun at them about their radicalism. Students are the most conservative people in the world, although they believe themselves to be the most radical. Let something happen twice, and it is a tradition. There is always a little group of them who are perfectly sure that monogamy and capitalism and all the other things that you and I have accepted as pretty good answers to the permanent problems of civilization, are all wrong. The only thing I beg of you to remember is not to take them too seriously, to keep your sense of proportion and your sense of humor. Life is always too serious to be taken too seriously.

The Critical Mind

And now, there are just one or two other types of minds that I might allude to. There is what we might call the critical mind—I mean the man

who is a real critic, whose mind is open to the truth, a man whose mind is free, who, for one instant, will not recognize any authority save the truth, and that which accords with the normal standards of experience, the man who frankly admits that all about him is mystery, problems that have not been solved, who realizes that every thinking person doubts at times, and therefore, who feels the glory and the fascination and the challenge of life just in this, that all about him are things that need to be solved.

Somebody, centuries ago, evolved the figure which Emanuel Kant made use of 100 years ago, "The World of Knowledge might be compared to an Island of Certainty, with its Border of Belief, and its great Ocean of the Unknown." We forget the beautiful shore and the solid rock upon which our feet are standing. Yet there is the critical mind that ought to take into consideration all of these things.

The Creative Mind

Then there is the creative mind. Oh, I beg of you, I beg of you to use any influence you have to keep alive any spark of originality that you see anywhere, but don't be disturbed if it comes in unconventional forms, but if you see somebody who is trying to do something that never has been done before, if you cannot help him, please stand by with your head bowed in sympathetic silence, for what America needs is creative minds, minds which can dig, minds which can work, minds which have initiative, minds which can create the answers to the problems with which you and I are baffled today.

What kind of a mind are you bringing to your work, to yourself, to your family, to your office, to your organization, to your community, and to the world, What kind of a mind is it, that mind of yours?

Now, men and women, would you care to have me tell you what I imagine to be a pretty ideal type of mind, whatever your own immediate circumstances? Now there are a good many things that I might say that you ought not to do but I am going to be very positive, and forget all of that, and say this—that I am of the impression that however much of native endowment you may possess, whatever the psychological measurers might tell you if you went in and had yourself tested, I am of the impression that the finest thing that I could say to you would be this, that you must have a thinking mind. You know that Emerson once asked, "What is the most difficult thing in the world?" And his answer was, "To think." And the difficulty with Americans today is this, that we are so prone to accept things upon authority; if we see something in a newspaper, it is true—you know how it is. It is true largely because a lot of other people know the same thing.

Now don't misunderstand me. I think our newspapers today are infinitely better than they were ten years ago, and there is no group of people in our community that is striving harder to do what they ought to do, I believe, than our newspapermen. But take even our most carefully prepared scientific books—how many of you, as you read a book and look at the printed pages as you see them there, conclude that they must be true—have you ever stopped to think that you can take any of these books and find mistakes on every page of them? Probably the only reasons that men write scientific books is that other men can find mistakes and then write better books.

We must be extremely careful to recognize the overwhelming difficulties confronted by the person who proposes to think. What are some of the

difficulties you are going to run into? Oh, how I would like to tear your mind to shreds tonight if there were time. You run into two or three things that you are not, as a rule, conscious of. The first problem that you will have if you are going to have a thinking mind are those prejudices that you are constantly clinging to. How you cling to an idea just because it happens to benefit you personally. Have you stopped to think how you cling to ideas that you have had without any thought of where you got got them, or whether they are true or not? Have you stopped to think of how you oppose other ideas just because you don't know anything about them, and particularly how you oppose ideas because somebody in your group got the idea before you did? You remember, therefore, if he thought of it first, it is not true. And have you ever stopped to think of the remarkable facility that that mind of yours has to forget every idea that you come in contact with that you are opposed to? If you run into an idea that you don't like, you just cast it aside like that, without every stopping to examine it. Your big problem, if you are going to have a thinking mind, is the problem of thinking in spite of your prejudices, for every one of us is tempted to pre-judge a case on the basis of partial information.

Popularity Should Not Influence Your Thinking

There is another thing, and that is not only thinking and your prejudices, but thinking and this question of popularity. You know how we are all highly sensitive to the judgment of our colleagues. You know I am very sensitive to what other university presidents think about what I do, and you are very sensitive as to what other people think of what you do. We want to be popular. There is nothing so fatal to your thinking as the desire to be popular. Have you ever stopped to think that if you are going to think, base your judgments upon facts, you cannot be concerned at all about whether your ideas are popular or unpopular? Any public servant, any executive officer, any man who expects to count in this generation, must completely forget whether a thing is popular or unpopular, and ask himself, "Is it in accord with the unescapable facts of the issue with which I deal?" That is the only way that you can think, and, whether popularity is right or wrong, the thinking person will not be concerned overmuch about popularity. For what is popularity? It is just what a good many people happen to think casually.

Would you like a little chapter out of my experience, a very brief one? When I want to really find out something that is important, I don't go to a faculty meeting to find it out. Why, you know I can remember when I was president of another educational institution of higher learning in the East, and we had a faculty meeting in which a member had been urged to make a motion before the meeting. In the meeting he made the motion, talked against it, and voted for it. Now I don't think much of conclusions that come out of that kind of deliberation, but if I want to find out something that I think is sound, and upon which we can place dependence, I say to professors A, B, X, and Y, "Come in, I want to have a little talk with you," and when our minds have met. I have the judgment that what we come to a conclusion upon is right. It is not popularity that will count in your thinking. You cannot get a thinking mind that way.

Just one thing more about the thinking mind. The thinking mind is the one that just has the time of its life with problems. Most of you people run

away from problems, you don't like them, but the thinking person is the one who every time he sees a problem tries to hit it on the head, writes it right down, lives with it, never runs away from it until he gets the answer. Lots of people like to state problems, and, like Pilate of old, who said, "What is Truth?" run off without waiting to find the answer. That is the trouble with much of our American thinking. We don't take our problems and go right through them for the facts. What is the trouble with American public life today? It is, that we base our public decisions, not upon the facts, but we base them upon popularity, upon opinions and upon the noisy invocations and inflections of certain types of demagogues. I go so far as to say that if we are to arrive at satisfactory solutions of public problems such as the one with which President Alfred has been dealing tonight, that we will do it, not by creating commissions to regulate them, but we will do it by employing the best trained, most scientific minds of the country in that field and give them a commission to set before us the facts in such terms that a student in the sixth grade of the public school could understand what their conclusions are. The trouble with the American railways tonight is that the public doesn't know what they ought to know about them. The trouble is that these decisions are made, not on the basis of scientific facts such as were given to us tonight, but on the basis of all kinds of policies and currents and cross currents that have little to do with the actual welfare of the American people. And if you and I are to be worthy citizens of a democracy we must insist, first, upon getting facts.

Tonight in the City of Detroit there are twenty centers from which are going doctrines and ideas and points of view diametrically opposed to the things which you and I believe the Constitution of the United States of America stands for. What are you and I doing about it? First, are we finding out the facts which lead some of these people to think what they do think? Secondly, are we trying to find out what they mean? And thirdly, if we have the facts, are we insisting upon wise and timely legislation in keeping with the facts?

Now you know when I ride in these smoking compartments of Pullman cars somebody always brings up the questions that concern our international problems with these nations. I am not discussing the labor question now. And then I always say, when a man tells exactly what we ought to do with this or that problem, "Why don't we do it?" He says, "Don't you know why? Because it would be contrary to the interests of this group or this corporation or this class of society or this particular organization or this state or this region of the country"—and what I stand here to say to you tonight is this, that that mind of yours must be a thinking mind in that it demands solutions of our problems and the knowledge of the facts, and when it has them, that it shall then insist upon legislation, regardless of the consequences to any individual or group or class, so long as the welfare of the public in America is concerned.

Now I am almost done. What have I said? My first point was the primacy of your mind. My second point was the various types of minds, and just a hint as to what type of mind you thought you had. My third point was that probably the ideal type of mind for a citizen is the thinking mind, which will deal wisely with prejudices and with popularity and with problems.

My general question is this: How are you going to do it? How are you and you and you going to master your mind? It is the most precious

thing that you possess, and what are you doing about it? Sixty-six million people every week go to the moving picture shows. Now don't misunderstand me, I go too, so does my wife, sometimes she prefers to go to them to listening to my speeches. But as I heard somebody say recently, the moving picture show never embarrasses ones intellectuality.

And what is it I am trying to come to? With all the seriousness which I can command, it is this, that you, of our self-respecting citizens are going to insist upon it that you know a little something of the mastery of your own mind.

Now, again, let me say that it is difficult thus to forget the unit of personality, to say the mind acts on the body and the body acts on the mind, and nobody knows how it is done. I beg of you never to forget that you are a unit and not a mind and a will and a heart and all the rest, you are one thing. Therefore, this body of yours must have the right kind of sleep, the right kind of exercise and the right kind of food, and all the rest, and the right kind of mental hygiene too. The thing I want to come to is this, I imagine that every executive in this audience tonight has a budget for the corporation of which he is the head. I know that we have one at the University of Michigan. We set the limits. That budget expresses our policies. It shows us how we are going to spend our income, and it makes room also for a certain amount of flexibility. You have your financial budgets for your homes, you women, and all the rest of you, but I want to ask you this question: Have you, as an individual, a time budget? Have you set any policies for the use of your time? How many minutes a day are you actually insisting shall be used for the cultivation of this thing which, after all, will determine more than anything else your success and your usefulness? What are you doing about it? Are you actually reading, and when you are reading, do you read, or do you slide? When you listen, as to me tonight, do you think about the next bridge party or how you should have played a certain card, or how you ought to have played that thing on the ninth hole, or do you actually try to think what the man means by what he is attempting to say? Do you know how to listen? When you are with your friends, what do they mean to you? Are they time killers? Is the time used for idle gossip, or is there a reasonable, normal amount of thought exchanged? Do you know what mental grip is? Mental application? Do you know what it is to settle right down to the grind until you go right through a problem and not around it? If you do, I know why you are President, or why you are Secretary-Treasurer, or why you are one of the dominating influences in a great organization that is affecting the commerce of America today. It is because you have something with which you can think, and you know how to use it, and to train it, and to hold it in leash. No man will master his mind who hasn't strength of character. No mind is worth while that isn't a clean mind, and honest mind, a mind that has honor, that is straight and true and veracious in its thinking. That is what we must have, that type of mind, that is not influenced by wrong considerations and wrong motives and constantly thrown off its balance by this inevitable tendency to deflect towards selfishness. The only way you are going to get it is to take that mind in hand and make it the kind of a mind that you mean it to be.

I am not forgetting all the things to which I have alluded in recent psychological discoveries, but all of them concede that, granted you have what

you have, you can make more of it than you are doing today. The thing that I have come here to say to you tonight as business men of intelligence, the thing that I plead for, not only in education, but in your own individual work in your community, in your homes, in this nation, is this, that we can bring intelligence to bear upon the solution of all our problems. It means that day by day you must supplement that mind of yours, it means there must be mental spaciousness that can take in the thing that the world is trying to say, all of its unformulated, unmeditated, unexpressed yearnings and emotions that mankind today is feeling, and that is sweeping through civilization as a whole. These things you ought to sense and trace out and drag out of the air and make a part of yourself.

Men and women, the thing for which I plead tonight is a new emphasis in your work and in your life, and emphasis upon what I conceive to be the most precious asset that you possess, that mind of yours, and I am of the impression that in proportion as we take life seriously, in proportion as we are determined to grow and to evolve and to be better tomorrow than we are today, in that proportion are we going to give attention to that mind of yours, for "As a man thinketh in his heart, so is he."

THE MECHANICAL PROPERTIES OF SOME CHROME-VANADIUM STEELS

Abstract

This paper deals primarily with the mechanical properties of chrome-vanadium steels for the purpose of obtaining information which would have a practical value in the design and construction of apparatus in nitrogen-fixation equipment.

The tensile properties, hardness and microscopic structure as affected by different heat treatments were determined for a given series of chrome-vanadium steels. The series selected lends itself readily to a classification based upon changes in the concentration of carbon, vanadium and chromium.

It was found that in the carbon series, containing from .15 to 1.20 per cent carbon, 1.0 per cent chromium and .18 per cent vanadium, in the annealed state, an improved tensile strength and a lowered ductility resulted with an increase in carbon content. With heat treated specimens a similar effect occurred up to .60 per cent carbon. A rise in hardness accompanied the increase in strength.

The vanadium series, containing .30-.40 per cent carbon, 1.0 per cent chromium and from 0 to .65 vanadium, in the annealed state showed an improvement in toughness over the corresponding carbon-chromium series. The tensile strength was only slightly affected. Heat treatment developed an improvement in the tensile strength and hardness. Ductility falls off rapidly when the vanadium content exceeds .30 per cent. High reduction in area which is maintained over the entire group of vanadium steels reveals the the toughness or inherent ductility of this type of steel.

The chromium series, containing .30-.40 per cent carbon, .18 per cent vanadium and 0 to 14.5 per cent chromium, in the annealed state showed the tensile strength and hardness to remain quite uniform for increases in chromium content up to 2 per cent. In excess of 2 per cent, chromium increases the strength and hardness at the expense of ductility. Heat treatment intensifies the effects of chromium indicated in the annealed specimens.

The relation between mechanical properties and the addition of varying proportions of carbon, chromium and vanadium on the microstructure were observed.

Introduction

THE superior resistance to deterioration of chrome-vanadium forging steel of the type containing .30-.40 per cent carbon, 1.0 per cent chromium and .18-.20 per cent vanadium, over ordinary carbon steels in important parts of the equipment used in the manufacture of synthetic ammonia by the Haber Process[2], led to an extended investigation of the mechanical properties of a number of special steels which contained these two important alloying ele-

1. Published by permission of the Director, Fixed Nitrogen Research Laboratory, U. S. Dept. of Agriculture.

A paper presented before the Society. The author, J. S. Vanick, is metallurgist, Fixed Nitrogen Research Laboratory, U. S. Department of Agriculture, Washington, D. C.

ments[3]. Much of the work was undertaken for the purpose of obtaining information which would have a practical value in the design and construction of important units in the nitrogen-fixation equipment. The data presented in this paper were selected from an extensive series of laboratory tests which were made in preparing the steels for corrosion and servic tests.

Since chromium and vanadium improved the corrosion resisting properties of the alloy steel over ordinary carbon steel, it was thought desirable to determine the influence of various quantities of these two alloying elements upon an ordinary forging steel. With this in view, two series of alloys were outlined in which either the chromium or vanadium content was varied while the carbon content was maintained as nearly constant as possible. A third series of alloys was added, in which the chromium and vanadium contents were maintained while the carbon content was varied. Thus 3 series of steels were built; a carbon series in which carbon was varied from .15 to 1.20 per cent; a vanadium series in which vanadium was varied from 0.0 to 0.65 per cent, and a chromium series in which chromium was varied from 0.0 to 15.0 per cent. This wide range in the latter was chosen in order that steels of the commercially designated *stainless* type, might be included. The compositions[4] finally obtained are recorded in Table I.

Chrome-vanadium steels of the 1.0 per cent chromium and .18 per cent vanadium type are obtainable commercially, in varying carbon contents. Steels 2 and 3 of the carbon series, containing .30 and .58 carbon respectively were so obtained. These two steels were prepared by electric furnace process, cast into 9-inch square ingots, cogged down to 5-inch square billets and rolled into 1-inch round bars. The remaining steels were made by drawing 600 to 700 pounds of metal into a ladle and adding the necessary ferro-alloys. After allowing a reasonable time for the solution and diffusion of the addition, the metal was cast into 5-inch square ingots and subsequently rolled into 1-inch round bars. All of the bars were given an annealing treatment by heating to 1500 degrees Fahr. and cooling in the furnace.

All tensile tests[5] were made on the standard .505 inch diameter threaded specimen. In a few tests the proportional limit was determined by employing an extensometer. In most tests, the yield point was determined by the use of dividers and the 'drop of the beam.' Hardness was measured by the standard Brinell and scleroscope methods. Impact tests were made with a Charpy machine on the standard specimen, notched 5 millimeters with the 'U' type of notch.

Carbon Series

The mechanical properties of several steels varying in carbon and containing approximately 1.0 per cent chromium and .18 per cent vanadium,

2. The Direct Synthetic Ammonia Process. Jour. Ind. and Eng. Chemistry, 12, No. 9, Sept., 1920, p. 844.

3. The work described in this paper, represents a part of a larger program undertaken jointly by the Fixed Nitrogen Research Laboratory of U. S. Dept. of Agriculture, Bureau of Standards, and the Nitrate Division and Technical Staff of the War Dept. Credit is due Capt. E. Y. Titus and Dr. C. W. Bray of the Fixed Nitrogen Res. Lab. for initiating the study of the resistance to deterioration of various steels, in ammonia and its component gases, and for some of the preliminary work leading to the selection of some of the steels, described in this paper.

4. Acknowledgment is due H. A. Bright, Associate Chemist, Bureau of Standards, for the chemical analyses listed in this table.

5. Tensile and impact tests were under the direction of R. S. Johnson, Engineer-physicist at the Bureau of Standards.

have been described by Sankey and Smith (1, 2, 3)*, Griffiths (4) and others (5, 6). In each case the particular composition and heat-treatment of the steel must be considered. The advantage in tensile properties which the chromium vanadium steels possess over similar carbon steels has been quite generally conceded. The value of the alloys for most industrial purposes lies in the improvement they lend, when properly heat-treated, to the strength and toughness of the steels.

Annealed Steels

The effect of carbon upon the tensile, hardness and impact properties is shown in Fig. 1. These properties represent the condition of the steel

Table I

Composition of Steels

Number	C	Mn	P	S	Si	Cr	V
			Carbon Series *Part A*				
1	.16	.55	.023	.023	.34	1.03	.20
*2	.30	.68	.012	.024	.26	.93	.18
3	.58	.68	.011	.017	.23	.73	.18
4	1.16	.55	.022	.018	.20	1.06	.20
			Vanadium Series *Part B*				
1	.40	.53	.018	.023	.18	1.05	.02
2	.37	.52	.018	.018	.20	1.05	.07
3	.35	.37	.020	.013	.20	1.02	.14
*4	.30	.68	.012	.024	.26	.93	.18
5	.37	.55	.018	.019	.18	1.07	.31
6	.27	.34	.025	.011	.29	1.24	.65
			Chromium Series *Part C*				
1	.38	.39	.017	.022	.27	.04	.19
2	.29	.53	.015	.011	.16	.51	.28
*3	.30	.68	.012	.024	.26	.93	.18
4	.31	.48	.011	.011	.12	2.01	.34
5	.33	.37	.028	.013	.26	7.70	.18
6	.42	.35	.025	.009	.06	14.40	.18

* A commercial type of chrome-vanadium steel about which the compositions of the remaining alloys were built.

after an 8-hour anneal at 1500 degrees. Fahr. The increase in tensile strength and hardness accompanied by a decrease in ductility and greater brittleness as measured by the impact tests agrees in general with the well-known influence of carbon upon these properties. The connection between the properties indicating strength and those indicating ductility and toughness obeys the familiar inverse relation; the ductility falling off rapidly as the tensile strength rises with the increase in carbon. The tensile properties of the alloy steels compared to those of the corresponding carbon steels hold their advantage over the latter, through the range of carbon, investigated. The advantage is slight for the lower carbon steels, but increases rapidly with the increase in carbon.

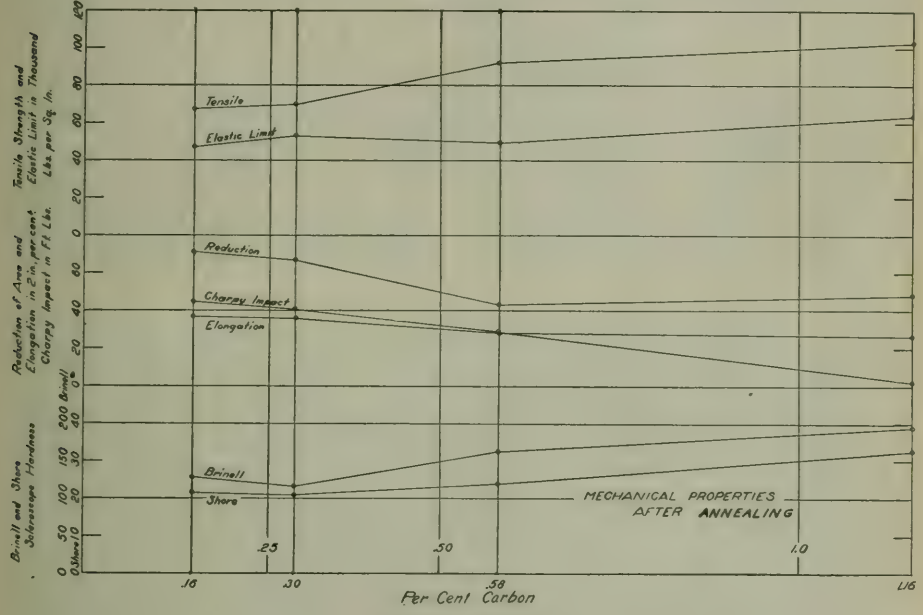
Heat Treatment

The quenching temperature range throughout which, a refining of the texture was produced, was determined with the aid of the fracture test,

*Figures appearing in parentheses refer to bibliography at the conclusion of this paper.

hardness measurements and the microscope. For the fracture tests, a 1-inch round bar, notched at 1-inch intervals was heated through a long thermal gradient, varying from the cold to fusion. The resulting fractures varied from the granular type in the cooler portions, through the extremely fine-textured types of the refining range to the coarsened or crystalline types of the highly heated portions. The positions of the types of fracture along the bar were noted and the corresponding temperatures estimated. From the estimates, a series of notched specimens were heated to different temperatures within the refining range. The hardness and structure of these specimens were determined and the typical fracture of each, examined.

The influence of different quenching temperatures within the refining range upon the hardness, may be observed from the data recorded in Table



CARBON SERIES

Fig. 1. Mechanical Properties After Annealing at 1500° F. for 8 Hours.

II. Higher temperatures further increase the hardness. In the case of the 1.16 per cent carbon steel, the increasing hardness is carried into the region in which the determination of hardness by the Brinell method, becomes unreliable.

The increasing hardness, with increasing temperatures is undoubtedly caused by the solution of the iron-chromium-carbon compounds in the austenite prevailing at the high temperatures. The temperature at which an appreciable absorption and dispersion of the carbides occurs in the solid solution is marked by a sharp increase in hardness. The lower temperatures at which an increase in hardness appears in the higher carbon steels, is in keeping with the well-known effect of carbon in lowering the upper transformation or Ac_3 point upon heating and the effectiveness of the alloys present, in assisting in preventing the occurrence of the reverse transformation upon quenching. The influence of these alloys upon the critical points of the various steels

*A paper by the author presented at the Detroit convention entitled *Thermal Transformations of Some Chrome-Vanadium Steels.*

used in this investigation, will be published in a later issue of TRANSACTIONS.*

The effect of the increasing carbon content upon the hardness of different steels which have been quenched from identical temperatures, is illustrated in Fig. 2. A progressive increase in hardness with an increasing carbon content is shown.

The effect of various quenching temperatures upon the tensile properties of the heat-treated steels is recorded in Table III. An increase in strength and hardness with increasing carbon, is noticeable. The failure of the high-carbon steel to develop a high tensile strength corresponding to its projected place in the increasing strength movement, may have been caused by the low quenching temperatures and the comparatively high tempering temperature which were employed in its treatment. Obviously, higher quenching tempera-

Table II
Carbon Series
Hardness After Quenching Treatments

No.	Chemical Composition				Quenching Temperatures—Degrees F.										Hardness
	C	Mn	Cr	V	1300	1350	1400	1450	1500	1550	1600	1650	1700	1750	
1	.16	.55	1.03	.20	....	....	....	259	255	273	273	393	399	380	Brinell
	....	....	....	....	....	....	....	36	38	37	37	53	50	54	Scleroscope
2	.30	.68	.93	.18	....	....	....	....	444	460	475	477	....	....	Brinell
	....	....	....	....	....	....	....	....	59	63	65	67	....	....	Scleroscope
3	.58	.68	.73	.18	....	....	....	....	627	578	652	....	....	....	Brinell
	....	....	....	....	....	....	....	....	73	70	82	....	..	....	Scleroscope
4	1.16	.55	1.06	.20	217	217	223	652	782	782	782	....	....	....	Brinell
	....	....	....	....	28	31	33	70	84	86	86	....	.....		Scleroscope

tures than those used, are necessary in order that this steel may occupy a position of greater strength.

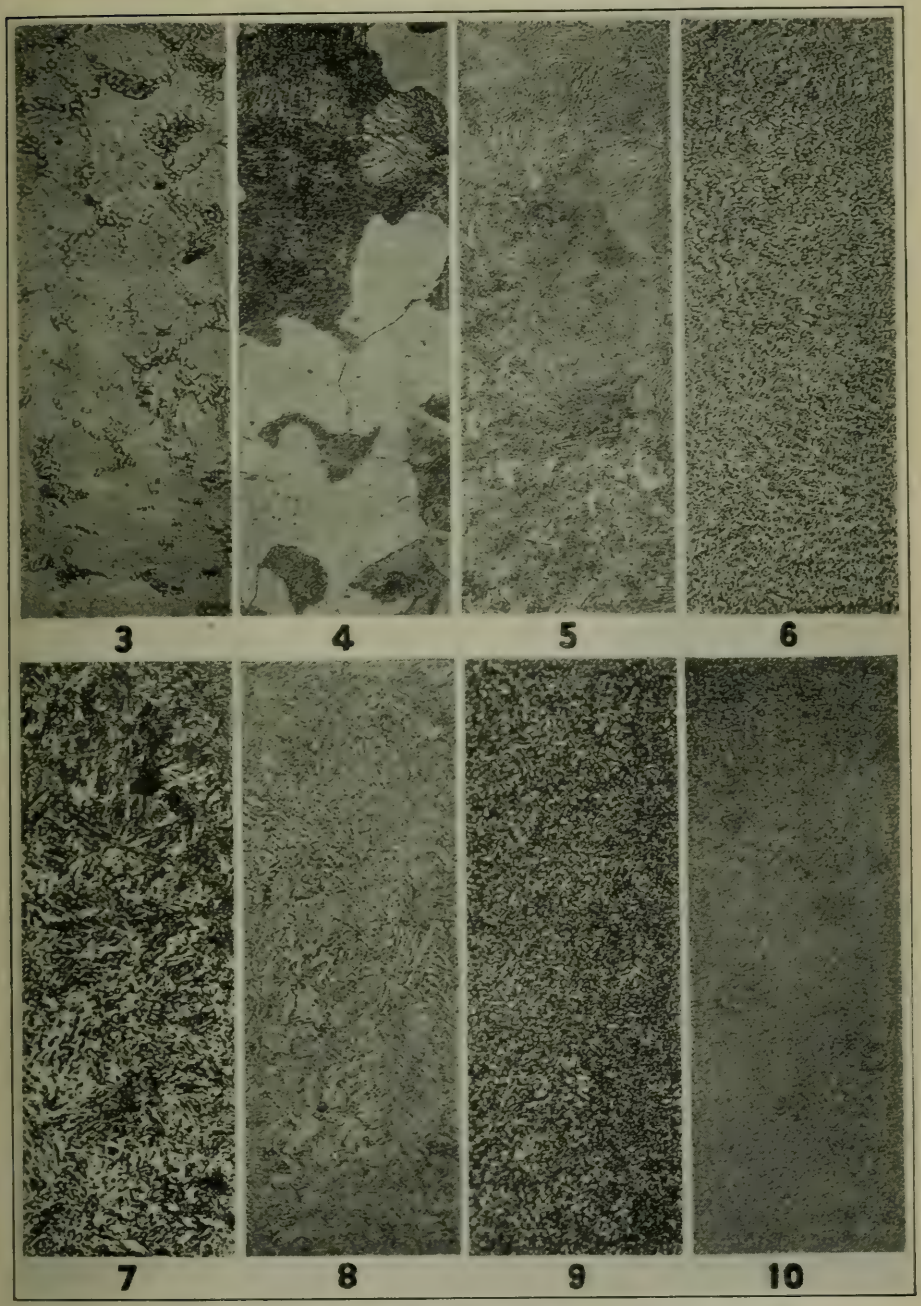
For each steel, increasing quenching temperatures are accompanied by greater strength and lowered ductility. The importance of the latter property in controlling the application of the steel to most industrial purposes is apparent. Consequently the quenching temperature which may be used is limited in part by its relation to the resulting ductility and toughness.

Microstructure

The microstructures of the annealed steels are illustrated in Figs. 3 to 6. The structure in general, resembles that of the corresponding carbon steels. In the hypo-euctectoid steels, the normal constituents, pearlite and ferrite appear uniformly distributed throughout the mass. The high carbon steel shows the usual cementite precipitation.

A few important points of difference between the structure of the alloy steels and the corresponding carbon steels, may be mentioned. For example, McWilliam and Barnes (*7*), in describing the influence of .2 per cent vanadium upon the structure of different carbon steels, report the occurrence of varieties of pearlite, differing in color. This effect is in evidence in all of the pearlitic steels examined which contain the alloying elements. Differences in the resistance to etching, due to small variations in the alloy content of the individual pearlitic patches, undoubtedly are responsible for the color effects.

The alloys are capable, when present in sufficient quantity, of constricting the pearlitic areas thus making the steel appear to contain less carbon than the quantity actually present. Both vanadium and chromium exert this property. In the present series of carbon steels, chromium is probably most active. In Fig. 3, for example, the normal lamellar type of pearlite is replaced by the granular type. In this case the ratio of carbon to chromium is approximately



CARBON SERIES

Microstructure of Annealed (1.0% Cr.,—.18% V) Carbon Steels. Specimens Etched in 2% Alcoholic Nitric Acid. Magnification × 500. Fig. 3. Carbon .16%. Fig. 4. Carbon .30%. Fig. 5. Carbon .63%. Fig. 6. Carbon 1.16%

Microstructure of Quenched and Tempered (1.0% Cr., .18% V) Carbon Steels. Specimens Etched in 2% Alcoholic Nitric Acid. Magnification × 500. Fig. 7 Carbon .30%. Quenched from 1600°F. Fig. 8 Same as Fig. 7. Tempered at 1050°F. Fig. 9 Carbon 1.10%. Quenched from 1550°F. Fig. 10 Same as Fig. 9. Tempered at 1050°F.

6 to 1. As the quantity of carbon increases, the coalescence or granulation becomes less marked. The alloys are, however, capable of disengaging the pearlite from its characteristic lamellar form, into shorter lamellae of a less orderly arrangement. The size of the pearlite patches within a pearlitic area is therefore smaller than that prevailing in a corresponding carbon steel. The solution of the alloys in the cementite should increase the inherent strength of the cementite lamellae. The shorter lamellae of the pearlitic patches would tend to make the path of rupture through this constituent more intricate compared to the course taken through the longer and more orderly arranged lamellae of the ordinary carbon steels. The detached lamellae scattered throughout the ferrite grains would undoubtedly be effective in reinforcing the ferrite. These

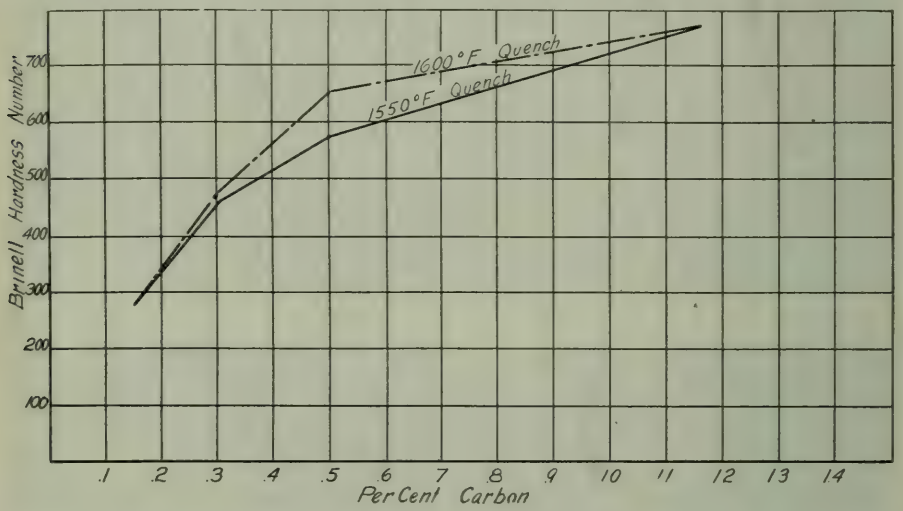


Fig. 2. Graph Showing the Increase in Hardness Resulting from an Increase in Carbon Content

various features of the structure, acting in unison in the metal under tension, would serve to improve the tensile properties of the alloy steels over those of the corresponding carbon steels.

Structures typical of the quenched and tempered steels are illustrated in Figs. 7 to 10. The structures of the quenched specimens follow the form of the corresponding carbon steels. The martensitic needles of the specimens quenched from successively higher temperatures adopt a longer sweep and coarsen progressively in agreement with the coarsening of the austenite from which they originate.

In the steels showing a pronounced precipitation of carbides, the solution of the carbides is not completed until comparatively high temperatures are reached. The partial absorption of the carbides may be observed in specimens quenched at temperatures rising to 1750 degrees Fahr. Above this temperature the absorption or dispersion is sub-microscopic and other methods are necessary to detect changes in structure and properties. It is evident, however, that the dispersion of the carbides of chromium and vanadium is not completed until comparatively high temperatures have been used. The structures of the tempered hypo-eutectoid steels retain the imprint of the structure of the quenched austenite. The hyper-eutectoid steel shows a pronounced precipitation of globular carbides.

Table III

Carbon Series

Mechanical Properties of Rolled Bars

Annealed 8 hours at 1500° F.

No.	Chemical Composition C	Mn	Cr	V	Mechanical Properties: Ultimate Strength Lbs. per sq. in.	Yield Point Lbs. per sq. in.	Elongation % in 2 inches	Reduction Area %	Brinell Numeral	Scleroscope	Charpy impact
1	.16	.55	1.03	.20	67,950	47,950	37.0	71.9	129	22	44.8
2	.30	.68	.93	.18	70,000	53,000*	36.0	67.0	116	21	40.7
3	.58	.68	.73	.18	92,400	49,950*	28.0	43.5	163	24	28.3
4	1.16	.55	1.06	.20	102,500	63,200	26.5	48.0	194	33	2.2

Mechanical Properties After Heat Treatment.

					Mechanical Properties: Ultimate Strength Lbs. per sq. in.	Yield Point Lbs. per sq. in.	Elongation % in 2 inches	Reduction Area %	Brinell Numeral	Scleroscope	Treatment Water Quenched**
1x	.16	.55	1.03	.20	114,650	103,100	22.5	68.0	231	42	1650° F
y	....	...	....	...	114,300	100,000	23.5	67.5	252	44	1700° F
z	....	...	....	...	122,200	112,450	20.5	67.0	255	45	1750° F
2x	.30	.68	.93	.18	145,800	107,000*	17.0	58.7	277	49	1550° F
y	....	...	....	...	152,850	115,000*	17.0	55.5	297	51	1600° F
z	....	...	....	...	158,800	117,000*	17.5	54.5	306	51	1650° F
3x	.58	.68	.73	.18	162,000	125,000*	16.0	49.5	293	49	1500° F
y	....	...	....	...	173,100	135,100*	15.0	45.5	332	52	1550° F
	....	...	....	...	180,800	140,000*	13.5	37.5	351	54	1600° F
4x	1.16	.55	1.06	.20	103,050	59,750	22.0	45.0	212	39	1400° F
y	....	...	....	...	114,250	83,200	20.5	39.0	221	43	1450° F
z	....	...	....	...	133,000	.....	17.0	31.0	262	45	1500° F

** All quenched specimens, tempered at 1050° F.
*Proportional Limit.

Vanadium Series

The early work of Arnold (8, 9) followed by the investigations of others, (10-12) established the value of vanadium as an alloying element. Subsequent developments have shown that .20 per cent or less of the element is sufficient to produce an improvement in ordinary carbon steel. The mechanical properties of carbon vanadium steels after various thermal treatments have been publishd by McWilliam and Barnes (7), Norris (12) and others.

Vanadium has further found a wide application in the manufacture of quaternary steels. Of these, the vanadium-chromium steels described in the previous section form an important group. The amount of vanadium in the

Table IV

Vanadium Series
Hardness After Quenching Treatments

No.	Chemical Composition				Quenching Temperatures—Degrees F.								Hardness
	C	Mn	Cr	V	1400	1450	1500	1550	1600	1650	1700	1750	
1	.40	.53	1.05	.025	196	396	415	438	495	512	....	....	Brinell
	...	...	....	....	27	51	54	56	67	62	....	....	Scleroscope
2	.37	.52	1.05	.07	....	578	578	566	600	600	616	578	Brinell
	...	...	....	....	....	56	57	60	66	66	69	67	Scleroscope
3	.35	.37	1.02	.14	....	....	512	495	555	546	555	512	Brinell
	...	...	....	....	....	....	64	66	68	67	68	65	Scleroscope
4	.30	.68	.93	.18	....	....	444	460	475	477	....	....	Brinell
	...	...	....	....	....	....	59	63	65	67	....	....	Scleroscope
5	.37	.55	1.07	.31	174	457	460	512	532	569	....	....	Brinell
	...	...	....	....	24	59	60	62	64	65	....	....	Scleroscope
6	.27	.34	.124	.65	....	....	202	340	402	430	452	460	Brinell
	...	...	....	....	....	....	53	59	56	59	65	65	Sclerosco p

forging steels seldom exceeds .20 per cent. In the steels described in this section, the vanadium addition was varied on either side of this amount. The composition of the vanadium series of steels used in the following tests, is listed in Table I. The vanadium content desired, had been quite closely approached although the close control of the quantity of the remaining elements present, encountered practical difficulties. In view of the very small quantities of vanadium added, differences in the chromium, manganese and carbon contents must be considered in interpreting the data obtained. With this precaution in mind, the limits within which vanadium may be said to improve the steel under the conditions of heat-treatment applied, can be derived from the test data.

Annealed Steels

The tensile test data are listed in Table V. The annealed specimens show comparatively small differences in tensile properties. Fig. 11 graphically shows the narrow range through which these properties move. In comparing the properties of the steels in the order of increasing vanadium, an improvement in the toughness as measured by the yield point, per cent elongation, and reduction, may be followed. This improvement appears to be greater than the decrease in carbon would warrant, thus suggesting its connection with the increasing vanadium content[6].

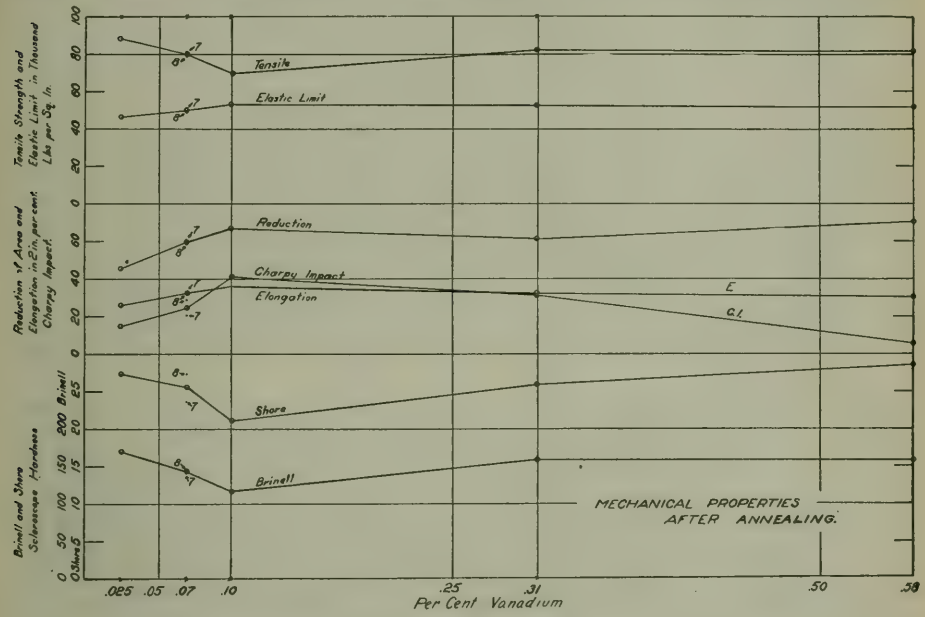
Heat Treatment

The quenching temperature ranges within which a macroscopic refining

6. The relative value of vanadium and chromium in a steel containing .40 per cent carbon may be compared from the test data on steel No. 1 of Table V and Table VII.

of the texture occurred, were obtained by the fracture method. This method roughly established the quenching range between 1450 and 1750 degrees Fahr. for the entire series. An examination of the microstructure and the determination of the hardness of the quenched specimens further restricted this range for each individual steel.

An inspection of the hardness data obtained from tests on the quenched specimens, shows, as would be expected, that hardening begins at 1450 degrees Fahr. and increases gradually with higher quenching temperatures. The hardness reaches a maximum at 1700 degrees Fahr. thus suggesting a maxi-



VANADIUM SERIES

Fig. 11. Mechanical Properties After Annealing at 1500°F. for 8 Hours.

mum diffusion of the carbides at this temperature. The increase in hardness, accompanying increasing quenching temperatures, is graphically shown in Fig. 12. The addition of a small quantity of vanadium to the chrome-carbon steel, slightly increases the hardness. Changes in hardness bear a more direct connection with the carbon content of the steel, thus indicating that small differences in carbon are capable of obscuring the hardening effect of small variations in vanadium.

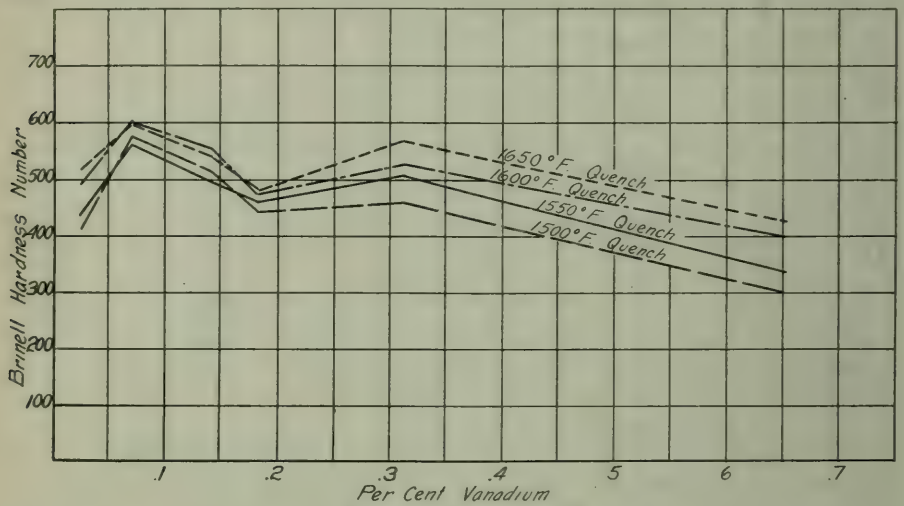
The effect of different quenching temperatures upon the tensile and hardness properties of the tempered steels is recorded in Table V. The tensile and hardness properties increase, in general, with an increase in the quantity of vanadium added. The ability of the heat treated steels to retain a high degree of ductility is expressed in the high values for the reduction of area. The steel has the ability to deform severely in a localized section thus giving rise to a high reduction of area although it is attended by a decreased elongation. This property cannot be attributed to vanadium alone since chromium steels, containing up to 2 per cent chromium, produce similar results. The quantity of chromium necessary to produce this effect is greater however, thus indicating the more intensive activity of vanadium in this respect.

A gradual increase in tensile strength and hardness may be noted for

individual groups of identical composition which have been quenched in the 1550 to 1650 degrees Fahr. range. There is apparently no advantage in quenching from temperatures higher than 1650 degrees Fahr. For most practical purposes, 1650 degrees Fahr., need not be exceeded.

Microstructure

The effect of vanadium upon the constitution and structure of different steels, has been described by several authors. In each case, the condition of the steel with reference to its composition and heat treatment, must be considered to successfully interpret the significance of small changes in structure. Frequently large differences in composition obscure the positions of



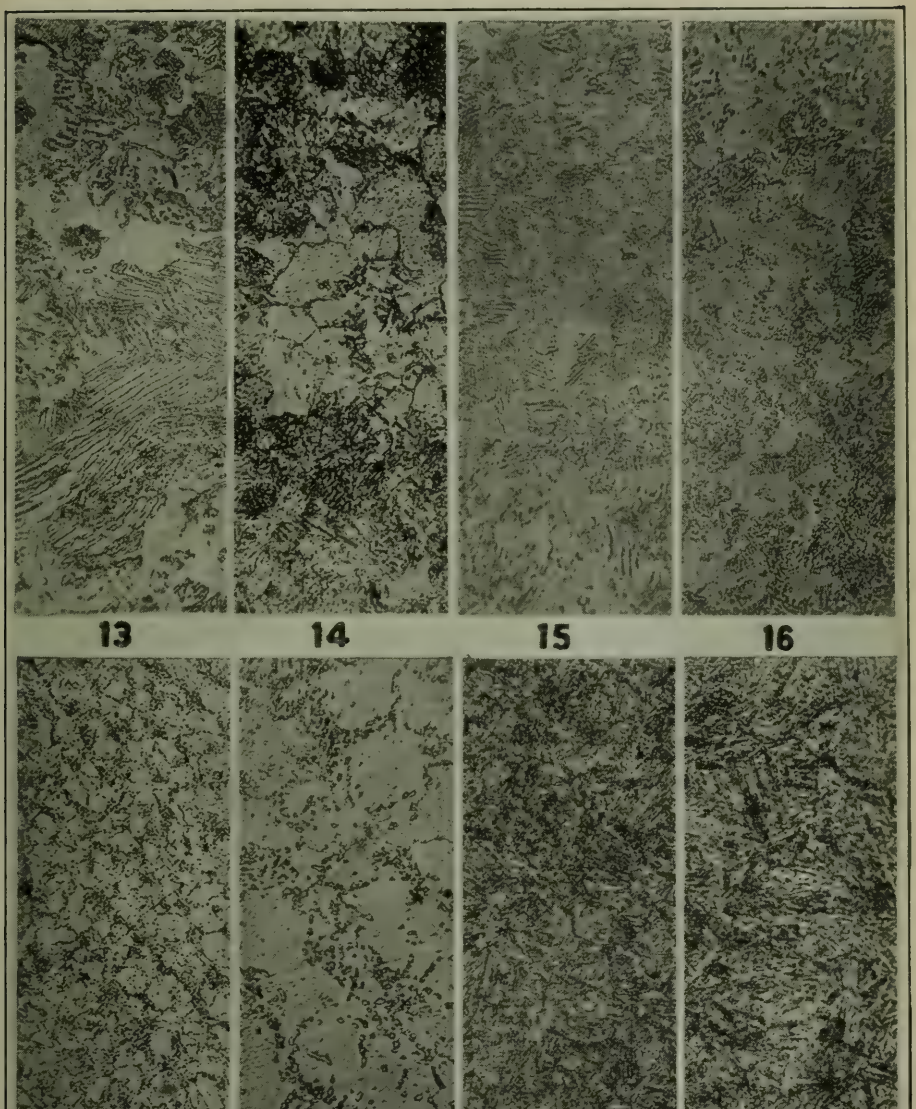
VANADIUM SERIES

Fig. 12. Graph Showing the Changes in Hardness (Brinell) with the Addition of Vanadium.

sharp internal changes. Since the vanadium content of this series of steels varies through a comparatively narrow range, and the ratio of carbon to chromium is nearly constant the effect of vanadium upon the microstructure can be closely followed. Figs. 13 to 18 illustrate the structures typical of the annealed specimens. In general, the relation between the composition and the structure follows the discussion given under the description of the structure of the carbon series of steels.

The smoothly developed grains of pearlite characteristic of a carbon steel are succeeded by smaller patches of a less regular form. The ferrite grains are smaller and frequently cut up by scattered strands of cementite or small aggregates of pearlite. Like chromium, vanadium is active in disturbing the orderly grouping of the pearlitic lamellae. Fig. 13 illustrates the irregular arrangement which the pearlitic lamellae adopt. On account of the small amount of vanadium present in the example cited, the effect is largely caused by chromium. However, as mentioned above, both elements act similarly.

As the quantity of vanadium increases, the pearlitic areas are considerably reduced and their individual lamellae, correspondingly shortened. Figs. 15 and 16 illustrate these conditions. With a further addition of vanadium the cementite lamellae are reduced to aggregates of globules and the pearlitic areas adopt the granular form. Figs. 17 and 18 show this particular form of structure. Small ferritic grains are bordered by colonies of the granular



VANADIUM SERIES

Microstructure of Annealed (.30—.40% C.,—1.0% Cr.) Vanadium Steels. Specimens Etched in 2% Alcoholic Nitric Acid. Magnification × 500. Fig. 13 Vanadium .025%. Fig. 14 Vanadium .07%. Fig. 15 Vanadium .14%. Fig. 16 Vanadium .31%. Fig. 17 Vanadium .65%. Annealed × 100. Fig. 18 Same as Fig. 17 × 500. Fig. 19 Same as Fig. 17. Quenched from 1650°F. × 500. Fig. 20 Same as Fig. 13. Quenched from 1650°F. × 500.

Table V

Vanadium Series
Mechanical Properties of Rolled Bars

Annealed 8 Hours at 1500° F.

No.	C	Mn	Cr	V	Mechanical Properties: Ultimate Strength Lbs. per sq. in.	Yield Point Lbs. per sq. in.	Elongation In 2 inches %	Reduction Area %	Brinell Numeral	Scleroscope	Charp Impact
1	.40	.53	1.05	.02	88,250	46,250	26.0	45.8	170	27	14.6
2	.37	.52	1.05	.07	80,300	50,950	33.0	59.9	143	24	20.1
3	.35	.37	1.02	.14	78,750	49,000	32.0	59.3	144	27	29.8
4	.30	.68	.93	.18	70,000	53,000*	36.0	67.0	116	21	40.7
5	.37	.55	1.07	.31	82,750	52,300	31.5	61.0	159	26	31.3
6	.27	.34	1.24	.65	81,500	51,300	30.0	70.3	158	29	5.7

Mechanical Properties after Heat Treatment

Quenched and Tempered

											Treatment** Quenched
1x	.40	.53	1.05	.02	119,750	94,500	22.0	66.5	259	49	1550° F
y	....	...	....	...	113,400	93,500	21.5	65.5	255	49	1600° F
z	....	...	....	...	124,750	106,750	20.0	63.5	255	49	1650° F
2x	.37	.52	1.05	.07	132,400	121,100	20.0	59.0	282	48	1600° F
y	....	...	....	...	132,900	119,400	20.5	59.5	286	49	1650° F
z	....	...	....	...	134,850	121,400	20.0	58.0	289	49	1700° F
3x	.35	.37	1.02	.14	144,800	135,500	16.5	57.8	302	50	1600° F
y	....	...	....	...	152,350	145,001	15.5	55.5	321	50	1650° F
z	....	...	....	....	158,800	147,500	15.0	52.7	338	46	1700° F
4x	.30	.68	.93	.18	145,800	107,000*	17.0	58.7	277	49	1550° F
y	....	...	....	...	152,850	115,000*	17.0	55.5	297	51	1600° F
z	....	...	....	...	158,800	117,000*	17.5	54.5	306	51	1650° F
5x	.37	.55	1.07	.31	119,500	110,450	21.5	64.0	263	48	1550° F
y	....	...	....	...	130,700	122,750	19.5	67.0	269	50	1600° F
z	....	...	....	...	132,650	128,300	19.5	58.5	286	50	1650° F
6x	.27	.34	1.24	.65	165,000	147,900	15.0	55.0	332	49	1650° F
y	....	...	....	...	169,200	159,200	14.0	51.0	335	48	1700° F
z	....	...	....	...	160,200	144,000	11.0	55.4	344	50	1750° F

* Proportional limit

** All specimens tempered at 1050° F. after quenching.

carbides. The ferritic grains are further cut up by thin segmented strands or isolated globules of the complex carbides. The structure consists of a ferritic matrix cut up by a net work of the carbidic globules. The slow cooling of the austenitic solution permits the excretion and concentration of the carbidic globules at the ferritic grain boundaries.

The relation between the quantity and distribution of the two principal components of the structure is reflected in the tensile properties. Vanadium and chromium are but slightly soluble in ferrite when cementite is present. The solution of the two alloys would be expected to increase the tensile strength. Of the two elements, vanadium is more powerful in concentrating the cementite into the globular form. The concentration of the cementite into globules, liberates large areas of the ductile ferritic component. The unusual ductility must result.

Figs. 19 and 20 illustrate the structure of the quenched steels. The structures resemble those of the previous series and the same general remarks apply to both. The degree of coarseness of the martensite appears to be lessened in favor of those steels containing a greater amount of the alloy. The tempered structures largely retain the imprint or configuration of their martensitic predecessors.

Chromium Series

The value of chromium as an alloying element has long been recognized. The early investigations of Hadfield (13), Guillet (14, 15) and others (11, 16, 17), indicated the effect of the element upon the physical properties of steels. Chromium, alone, or in combination with nickel, tungsten, molybdenum and vanadium forms a number of highly useful steels. The most familiar types of chromium steels contain 1 per cent or less of the alloy. Steels containing more than 1 per cent are regarded as special purpose alloys. Excluding tool steels, few alloy steels are made with a chromium content in the 2 to 12 per cent range. Above 12 per cent, the corrosion resisting *stainless* steels come into use. The mechanical properties of the high chromium steels have been described by several authors (18, 20). The prompt response of the high chromium steels to changes in composition and heat treatment demands that these two factors be considered in the interpretation of test data.

In the steels used in the following tests the chromium content was chosen to include steels of the *stainless* or high chromium type. In addition the vanadium content of .18 per cent was desired. Some difficulty was experienced in maintaining a fixed vanadium content throughout the series. The compositions recorded in Part C of Table I, were finally accepted.

Annealed Steels

The influence of chromium upon the mechanical properties of the annealed steels is recorded in Table VII. No marked change is noticeable until 7.7 per cent chromium is reached. At this point a maximum tensile strength is attained which is maintained with the addition of chromium up to 14.4 per cent. The influence of the small amount of vanadium may be disregarded except in the case of the 2 per cent chromium steel, in which a larger proportion of vanadium evidently interrupts the true effect of chomium.

Heat Treatment

Specimens representing each of the steels were quenched from different temperatures within their refining range as determined by the fracture test.

Table VI

Chromium Series

Hardness After Quenching Treatments

No.	Chemical Composition				Quenching Temperatures—Degrees F.										Hardness
	C	Mn	Cr	V	1400	1450	1500	1550	1600	1650	1700	1750	1800	1850	
1	.38	.39	.04	.19	174	228	232	241	241	251	....	....	....	....	Brinell
	...	...	.....	...	26	32	35	37	34	35	....	....	....	....	Scleroscope
2	.29	.53	.51	.28	191	210	225	227	262	277	386	477	....	....	Brinell
	...	...	...	...	31	33	32	34	37	39	48	57	....	....	Scleroscope
3	.30	.68	.93	.18	....	....	444	460	475	477	....	....	....	....	Brinell
	...	...	...	...	....	....	59	63	65	67	....	....	....	....	Scleroscope
4	.31	.48	2.01	.34	....	336	387	393	460	503	502	495	....	....	Brinell
	...	...	...	...	....	45	44	48	65	62	65	60	....	....	Scleroscope
5	.33	.37	7.70	.18	....	....	....	444	512	512	532	555	....	....	Brinell
	...	...	...	...	....	....	....	60	64	62	62	66	65	....	Scleroscope
6	.42	.35	14.40	.18	....	....	....	....	452	477	503	569	543	612	Brinell
	...	...	.....	...	....	....	....	....	63	64	65	68	67	71	Scleroscope

The fractures, hardness and microstructure were noted. A refinement in the texture of the fractured surfaces was included in a range varying from 1550 to 1850 degrees Fahr. Fine grained fractures of the porcelainic type were obtained in quenching the high chromium steels from temperatures as high as 1850 degrees Fahr. Temperatures above this were not investigated.

Table VI records some of the hardness data. A distinct increase in hardness occurs in specimens quenched from 1600 degrees Fahr. This temperature marks the position of a rapid dissociation of the carbides of chromium. The dissociation continues with increasing temperatures, the hardness increasing as the chromium compounds are further diffused. Quenching temperatures as high as 1850 degrees Fahr. are accompanied by greater hardness. Quenching a *stainless* steel in oil, French (20) obtained a maximum hardness at 1950 degrees Fahr., which was maintained to 2250 degrees Fahr., the final quenching temperature investigated. It is evident that the dispersion of the chromium carbides in the solution is not complete until these high temperatures have been attained.

Fig. 21 illustrates graphically the effect of chromium upon the hardness of the quenched steels. A rapid increase is obtained by adding 1 per cent chromium. An increase in chromium up to 7.7 per cent, further increases the hardness. Chromium in excess of this amount does not appear to add to the hardness of the metal. There is obviously a definite relation between the quantity of chromium and carbon, that determines the position of a maximum hardness. In addition the rate of cooling exerts a profound effect.

The effect of different quenching temperatures upon the tensile and hardness properties of the tempered steels is shown in Table VII. A gradual increase in tensile strength accompanied by a corresponding loss in ductility is shown. As might be expected, a higher quenching temperature for different members of identical composition is accompanied by a greater tensile strength, but decreased ductility. The very high quenching temperatures that are necessary to dissolve the carbides of steels containing large percentages of chromium, produce sharp changes in the mechanical properties. Caution must be used in applying steels so treated to service. For service as *stainless* steels, Hatfield (18) recommends a quenching in water from 1832 degrees Fahr. The *stainless* type of steel is inherently brittle due to its large chrom-

ium content. Quenching from the high temperatures that are necessary to develop the stainless qualities, render the steel, unfit for many other purposes. Where the corrosion factor is unimportant lower temperatures are preferrable.

Microstructure

Structures typical of the annealed steels are illustrated in Figs. 23 to 26. The structures of low chromium steels, annealed at 1500 degrees Fahr. are pearlitic, and in general, similar to those prevailing in an alloy-free steel of an equal carbon content. The change in the color of the pearlite and a

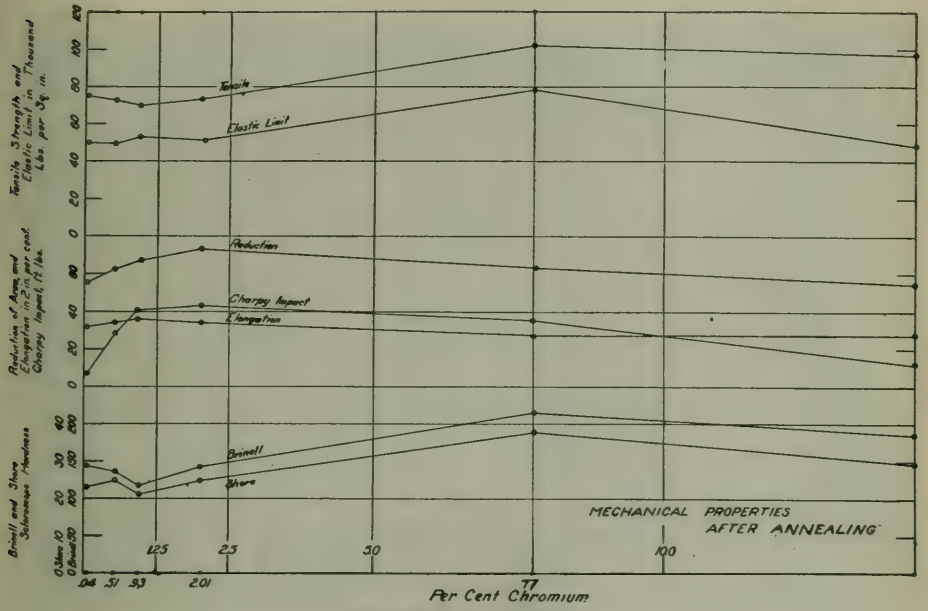


Fig. 21. Mechanical Properties After Annealing at 1500°F. for 8 Hours

gradual decrease in the volume of this constituent with an increase in chromium, is noticeable. As the quantity of chromium reaches 2 per cent, the pearlitic areas which would be expected to occur in an alloy-free steel, are constricted into irregular chords and globular particles. The structure, as shown in Fig. 24, consists of a ferritic matrix, spotted with patches of globular particles and thin segmented veins of the iron-chromium carbides.

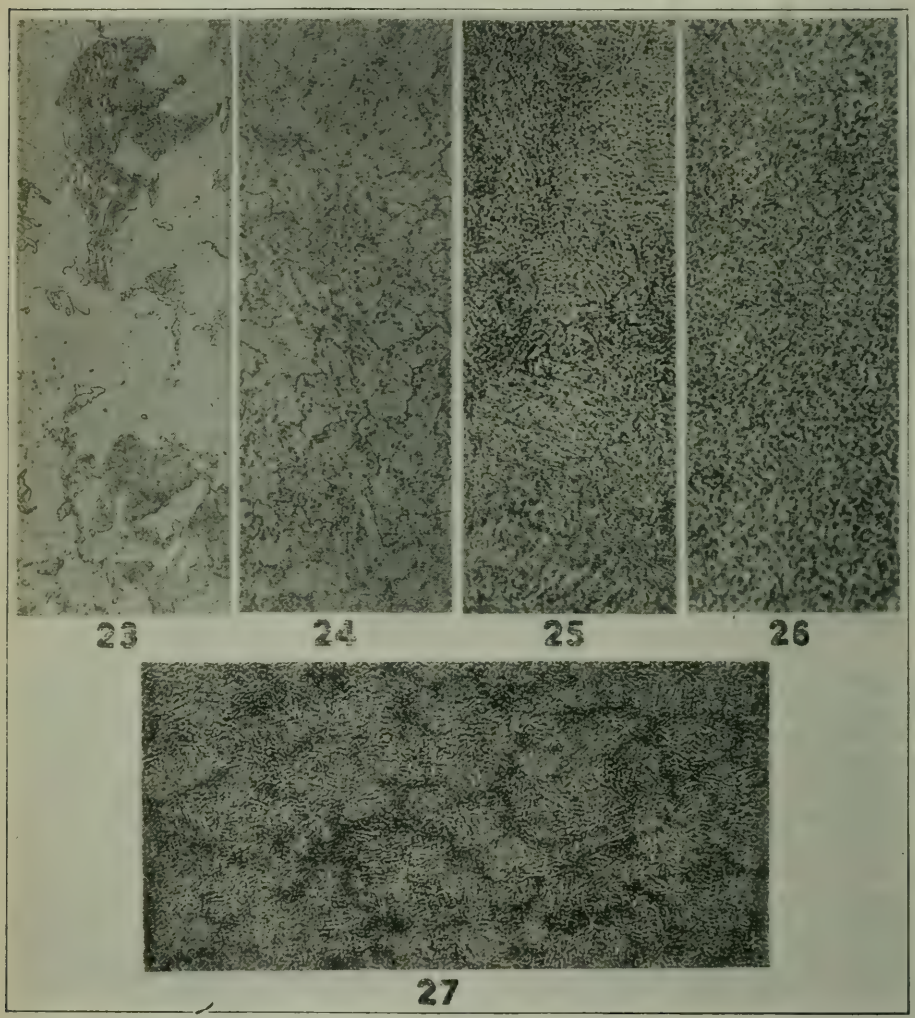
The relation drawn between the structure and the mechanical properties of the vanadium steels applies equally to the low chromium steels. The concentration of the cementitic component into the hard, complex carbide, particles, releases large areas of the ferritic component. This accounts in part for the improved ductility of these steels. As the quantity of chromium increases, changes in constitution[7] play an important part in the structure and properties. Important factors in determining the structure of the high chromium steels are; (a) the composition, (b) the temperature of heating, (c) the rate of cooling.

The microstructure of the high chromium steels is almost entirely martensitic, Figs. 25 and 26, representing steels which contain 7.7 and 14.4

7. The recent inestigations of Murakami (21), Edwards (22), and Monypenny (23), should be consulted for information relative to the structure and constitution of chromium steels.

per cent chromium respectively, show this structure. The needle-like form of martensite is not sharply developed. In its stead, the 'V' shaped valleys filled with minute carbide globules, outline the characteristic martensitic configuration. In Fig. 26, this structural pattern is completely lost in the heavy precipitation of carbide globules which thoroughly spatter the matrix. The increase in the quantity of chromium is thus reflected in the structure by an increase in the size or number of carbide particles. Apparently a portion at least, of the added chromium, enters into solution in the carbide globules.

The probable composition of the iron-chromium carbides has been sug-

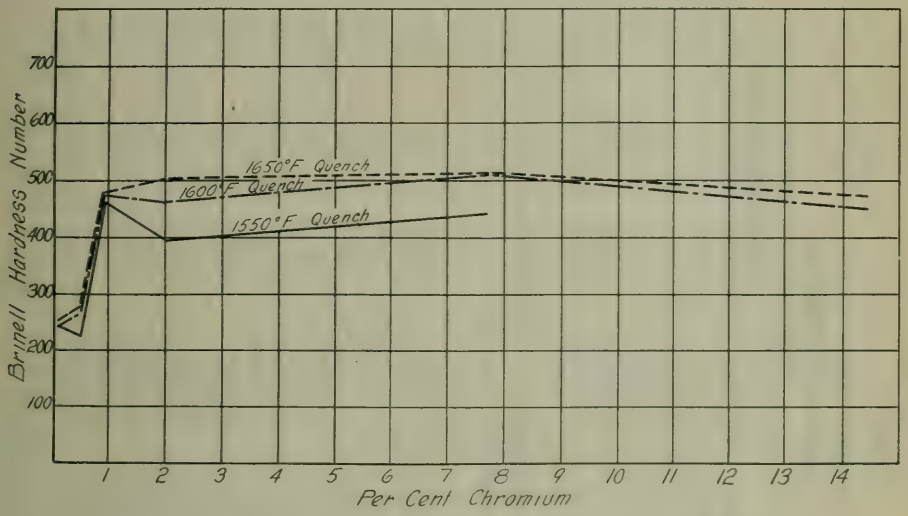


CHROMIUM SERIES

Microstructure of Annealed (.30—.40% C.,—.18% V) Chromium Steels. Fig. 23 Chromium .51%. Fig. 24 Chromium 2.01%. Specimens Etched in 2% Alcoholic Nitric Acid. Magnification × 500. Fig. 25 Chromium 7.70%. Fig. 26 Chromium 14.4%. Specimens Etched in a 50% Solution of 1 Part Nitric Acid, 3 Parts Hydrochloric Acid in Water. Magnification × 500. Fig. 27 Chromium 7.70% Same as Fig. 25, Showing Troostite Net-Work × 100.

gested by Murakami as a result of his magnetic analyses and etching tests. Attempts to identify the different carbides, by etching reagents have not been entirely successful. From the results of the etching tests, it is evident that the composition of the carbide globules varies with the initial temperature of heating, rate of cooling and alloy content of the steel under investigation. It is therefore difficult to predict the composition of the carbides and matrix without defining the conditions of heat-treatment.

It is conceivable that the composition of the carbides may vary from that of cementite to that of a carbide of chromium. Between these two carbides,



CHROMIUM SERIES

Fig. 22. Graph Showing the Changes in Hardness (Brinell) with Increasing Chromium.

a continuous series of double carbides may form in which the ratio of iron carbide to chromium carbide becomes smaller as the chromium content increases. Chromium would therefore replace a portion of the iron. Along this line of reasoning, it would be expected that the iron carbide and chromium carbide form a continuous solid solution which is not interrupted by definite points marking the formation of distinct double carbides.

Fig. 27 illustrates the appearance of a dark-etching network in the martensitic matrix of the 7.7 per cent chromium steel. The net work consists of very fine carbidic globules embedded in the darkened meshes. Since the addition of chromium to the steel retards the transformations on cooling and produces a structural condition similar to that obtained by an acceleration of the cooling rate, it is evident that the alloy content of the steel was such as to induce the partial transformation of the martensite into its decomposition products, in a manner similar to the formation of troostite in quenched or rapidly cooled carbon steel. The darkened meshes indicate that the abrupt transformation of austenite into troostite had occurred and been accompanied in the matrix by the less rapid transformation of austenite into martensite. The continuity of the darkened net-work marks the path of the austenitic decomposition along the boundaries of the former austenitic grains.

The structures of the quenched chromium steels are of particular interest in revealing the progress of the solution of excess carbides in the martensitic

Table VII

Chromium Series

Mechanical Properties of Rolled Bars

Annealed 8 hours at 1500° F

No.	Chemical Composition C	Mn	Cr	V	Mechanical Properties. Ultimate Strength Lbs. per sq. in.	Yield Point Lbs. per sq. in.	Elongation % in 2 inches	Reduction Area %	Brinell Numeral	Scleroscope	Charpy impact
1	.38	.39	.04	.19	75,150	50,000	32.0	55.7	143	23	6.6
2	.29	.53	.51	.28	72,800	49,500	34.0	62.2	136	25	27.6
3	.30	.68	.93	.18	70,000	53,000*	36.0	67.0	116	21	40.7
4	.31	.48	2.01	.34	73,750	51,400	34.0	73.2	143	25	43.1
5	.33	.37	7.70	.18	102,500	78,750	27.5	63.7	216	38	36.0
6	.42	.35	14.40	.18	96,750	48,100	27.5	54.8	185	29	11.2

Mechanical Properties after Heat Treatment

No.					Quenched and Tempered						Treatment Water Quenched**
1x	.38	.39	.04	.19	88,850	62,850	32.0	64.5	185	30	1500° F
y	....	...	....	...	89,300	64,000	32.0	66.0	186	32	1550° F
z	....	...	....	...	104,050	74,500	24.0	62.0	209	37	1600° F
2x	.29	.53	.51	.28	113,800	95,900	23.5	62.5	239	47	1650° F
y	....	...	....	...	123,000	104,850	22.5	58.0	269	47	1700° F
z	....	...	....	...	130,100	115,250	21.5	63.0	286	52	1750° F
3x	.30	.68	.93	.18	145,800	107,000*	17.0	58.7	277	49	1550° F
y	....	...	....	...	152,850	115,000*	17.0	55.5	297	51	1600° F
z	....	...	....	...	158,800	117,000*	17.5	54.5	306	51	1650° F
4x	.31	.48	2.01	.34	131,850	121,600	21.0	65.0	286	51	1600° F
y	....	...	....	...	134,250	126,000	20.0	64.5	293	52	1650° F
z	....	...	....	...	149,050	138,150	20.5	63.0	321	55	1700° F
5x	.33	.37	7.70	.18	189,650	155,000	13.0	46.7	368	58	1650° F
y	....	...	....	...	213,100	187,000	13.0	42.8	423	62	1700° F
z	....	...	....	...	215,000	194,900	12.5	40.0	441	65	1750° F
6x	.42	.35	14.40	.18	202,000	162,600*	8.0	23.2	387	41	1650° F
y	....	...	....	...	195,000	183,600*	7.0	18.7	364	48	1750° F
z	....	...	....	...	258,000	78,400*	2.5	1.3	477	67	1850° F

* Proportional Limit.

** All quenched specimens tempered at 1050° F

matrix. With small amounts of chromium, the structures follow the usual form, becoming martensitic as the quenching temperatures exceed 1500 degrees Fahr. Higher quenching temperatures do not coarsen the martensite to the same degree as that occurring in a corresponding carbon steel. This condition is undoubtedly associated with the influence of chromium. The gradual increase in hardness which these steels show when 1600 degrees Fahr. is exceeded, connects this change with the absorption of the complex carbides and the subsequent diffusion of the chromium and vanadium addition.

In the higher chromium steels, the hardness increases progressively as the temperature exceeds 1600 degrees Fahr. In the steel containing 14.4 per cent of chromium, the carbide particles become smaller as the temperature is increased and finally disappear at 1750 degrees Fahr. The absorption of the free iron-chromium carbides may be microscopically followed in specimens quenched from temperatures up to 1750 degrees Fahr. Above this temperature the distribution of the carbides is sub-microscopic as evidenced by the increasing hardness of steels quenched from temperatures exceeding 1750 degrees Fahr.

Tempering produces changes in structure similar to those occurring in carbon steels. The coarsened texture which is developed by quenching the low-chromium steels from high temperatures, is retained in the tempered matrix and recorded in the microstructure by the broader sweep of the former martensitic needles. As the temperature of tempering increases, a decomposition of the martensitic matrix occurs which is revealed in the structure by the roughening and blunting of the martensitic blades. At still higher temperatures, these markings are succeeded by wedge shaped or irregular, angular patches of an emulsified texture. The temperature of this decomposition appears to increase with an increase in the chromium content or a change to a higher quenching temperature.

In the steels containing 7.7 and 14.4 per cent chromium, which have been quenched from temperatures sufficiently high to absorb the carbide globules, tempering is accompanied by a gradual precipitation of carbides.

The net work of incipient troostite which forms upon quenching from lower temperatures, is preserved over a wide range during the tempering. The molecular changes which accompany tempering undoubtedly consist of a slow consolidation of the dispersed chromium, and carbon, into the complex double carbides which are gradually released from solution.

Summary

The tensile properties, hardness and structure and the changes in these properties with different heat-treatments were determined for a series of chrome-vanadium steels. The series lends itself readily to a classification based upon changes in the concentration of carbon, vanadium or chromium.

The carbon group containing 1.0 per cent chromium; .18 per cent vanadium and varying in carbon from .15 to 1.20 per cent showed in the annealed state an improved tensile strength and a lowered ductility with an increase in carbon. In the heat-treated specimens a similar effect occurs up to .60 per cent carbon.

Within the quenching temperature ranges investigated, the higher temperatures produce an improvement in tensile strength with an attendant loss in ductility. A rise in hardness accompanies the increased strength.

The vanadium group, containing .30-.40 per cent carbon; 1.0 per cent chromium and vanadium varying from 0.0 to .65 per cent, showed in the annealed state, an improvement in toughness, over corresponding carbon-

chromium steels. The tensile strength, is, however, but slightly affected. Heat treatment develops an improvement in tensile strength and hardness. The ductility as measured by the elongation, falls off rapidly when .30 vanadium is exceeded. The high reduction in area which is maintained over the entire group of vanadium steels, reveals, in the severe deformation over a localized section, the toughness or inherent ductility of the steel.

In the series of steels, containing .30-.40 per cent carbon, .18 per cent vanadium and 0 to 14.5 per cent chromium, the tensile, and hardness properties after annealing, remain quite uniform for increases in chromium up to 2 per cent. Chromium in excess of 2 per cent, increases the strength and hardness at the expense of the ductility. Heat treatment develops the influence of the element and intensifies the effects which are indicated in the annealed specimens.

The nature of the relation between the mechanical properties and the addition of different proportions of chromium, carbon and vanadium is suggested from an examination of the microstructures. In the annealed specimens, the well-known effort of chromium and vanadium to form carbides results in the combination of a portion of these elements with the cementite. The concentration of chromium and vanadium into complex carbides, causes a constriction and disruption of the pearlitic areas which in turn releases more ferrite and distributes the cementitic lamellae, more widely. The improvement in toughness of most of these steels is accounted for, by the release of a portion of the ferrite and the coincident reinforcement of the matrix by the distributed cementitic lamellae.

In heat-treating, higher quenching temperatures than those applied to carbon steels, are required to enforce the solution of the complex carbides. In steels containing a large amount of chromium, temperatures in excess of 1750 degrees Fahr. are necessary to enforce the solution of the complex carbides. Tempering produces the usual changes in structure which proceed, however, at a less rapid rate.

In conclusion, acknowledgment is due R. S. Tour, of the Fixed Nitrogen Research Laboratory, G. K. Burgess, of the Bureau of Standards and S. Tour of the Technical Staff, War Department, for the assistance that made this work possible.

Selected Bibliography

	Name	Title	Date	Publication	Volume	pp
(1)	Sankey and Smith	Heat Treatment Experiments with Chrome-Vanadium Steel.	1904	Proc. Inst. of Mech. Eng's.	Part IV	1235
(2)	J. Kent Smith	Journal of the Society of Chemical Industry Vol. XXV, pp. 291-295	1906	Journal Iron & Steel Institute —Abs.	Part IV	912
(3)	J. Kent Smith	Present Source and Uses of Vanadium	1904	Am. Inst. of Min. & Met. Eng's.	XXXVIII	702
(4)	L. J. Griffiths	Role of Chrome-Vanadium	1917	Am. Soc. for Test. Materials	17-2	33
(5)	R. R. Abbott	The relation between maximum Strength, Brinell Hardness and Scleroscope hardness in Treated and Untreated Alloy & Plain Steels.	1915	Am. Soc. for Test. Materials	Part II	43
(6)	American Vanadium Co.	Vanadium Steels.				
(7)	McWilliam & Barnes	Iufluence of Vanadium on Steels of Varying Carbon Contents	1911	Journal Iron & Steel Inst.	LXXXIII No. 1	294
(8)	J. O. Arnold	Record of the Discovery of the Influence of Vanadium on Steel.	1915	Journal Iron & Steel Inst.	XCI	442
(9)	J. O. Arnold & A. A. Read	The Chemical & Mechanical Relations of Iron, Vanadium & Carbon.	1912	Journal Iron & Steel Inst.	Part I	215
(10)	L. Guillet	Use of Vanadium in Metallurgy	1905	Journal Iron & Steel Inst.	Part II	118
(11)	A. M. Portevin	Special Ternary Steels	1909	Car. Schol. Mem.	I	28
(12)	G. L. Norris	Role of Vanadium	1917	Am. Soc. for Test. Materials.	17-2	20
(13)	R. A. Hadfield-Osmond	Alloys of Iron and Chromium.	1892	Iron & Steel Inst. Journal	No. 11	49
(14)	L. Guillet.	Quaternary Steels.	1906	Jour. Iron & Steel Inst.	No. 11	1
(15)	L. Guillet.	Les Aciers au chrome.	1904	Revue De Metallurgie	P. I	155
(16)	McWilliams & Barnes.	Some Physical Properties of 3 Per Cent Chromium Steels.	1910	Jour. Iron & Steel Inst.	No. 1	246
(17)	Arnold and Read.	Chemical & Mechanical Relations of Iron, Chromium and Carbon.	1911	Jour. Iron & Steel Inst.	No. 1	249
(18)	W. H. Hatfield.	Heat Treatment of Aircraft Steels	1917	Automotive Engineer	7	
(19)	Seidell and Horwitz	Physical Qualities of High Chrome Steel.	1919	Iron Age.	103, No. 5	291
(20)	H. J. French	Heat Treatment of High Chromium Steel.	1920	Chem. & Met. Engineering	23, No. 1	13
(21)	J. H. G. Monypenny	Structure of Some Chromium Steels.	5920	Jour. Iron & Steel Inst.	C. I.	493
(22)	T. Mura Kami.	Structure of Iron-Carbon-Chromium Alloys.	1918	Sci. Reports, Tohoku Imp. Univ.	7	218
(23)	Edwards, Sutton & Oishi	Properties of Iron-Chromium-Carbon Steels.	1920	Jour. Iron & Steel Inst.	Vol. C I	403

RESEARCH FOR ENGINEERING SOCIETIES

By Alfred D. Flinn

Aims and Agencies

RESEARCH is concentrated, directed endeavor to gain knowledge, new to the searcher. This paper is devoted to research in the natural sciences for the advancement of technology and industry under the auspices of the engineering societies. From the beginnings of human life necessity for sustenance and shelter has forced Man to learn more and more regarding his environment. In time it became desirable to go beyond the obvious,—to deduce and to predict. In the indistinct records of early civilization, evidences of the advancing search for knowledge are found, but the numbers engaged in the pursuit appear to have been very small. Progress in the remote ages was measured by milleniums. Then centuries began to count. Now the decades and even the days register advance so rapid that no longer is it possible for any individual to keep informed.

Great acceleration in research came with distinct improvement in means for social intercourse and for recording and disseminating knowledge. Each advance in science has increased the probability of other advances, not along the same lines alone, but also in other and frequently quite different fields. The number of workers, the variety and multiplicity of subjects and the diversity of applications have increased until the complexity has passed comprehension. Need for organization, co-ordination and co operation became urgent. But the initiation of these methods in research are but as of yesteryear. Only a very few of the world's oldest scientific societies have completed a century. Our oldest American engineering society was founded in 1848. According to the 1920 census, there are 136,000 technical engineers in the United States of America, exclusive of designers, draftsmen and inventors. The best available information gives about 150 national engineering societies, all more or less concerned with the advancement of the sciences and their applications to the well-being or destruction of Man.

A large number of these societies are actively engaging in investigations deserving the name "research." Frequently, however, these inquiries are questions of application or development rather than of research in fundamental science. This is natural and legitimate, for in the main, the engineer is concerned with applications and developments. Since the personal attainments, the care in operations, the equipment and the methods are often of the same order as those demanded by research in so-called pure science, the word research will be permitted in this paper to embrace both kinds of inquiry. Indeed, in many fields no sharp lines can be drawn between fundamental researches and inquiries into the applications of the knowledge gained. Indeed, in engineering, the art has frequently preceded the science.

The multiplicity of societies reflects variety of interests and also, to some degree, the tendency to create an independent agency for each new purpose. A few societies have important research departments. The tendency to independent action has some justification, but it has also

---

A paper presented at the Detroit convention, Research Symposium. The author, Alfred D. Flinn is Secretary, Engineering Foundation and Chairman, Engineering Division, National Research Council.

led to dissociation of groups which have much in common, with consequent disadvantages. An opposite or integrating tendency has also been in evidence during recent years. Today it is found, therefore, that the engineering societies have numerous independent research activities, but that a number of them have established some means of co-operation. First, there are a few societies, composed mostly of members of previously existing societies, which have been created principally for the study of a certain group of subjects and their applications in engineering and industry. By way of example, the American Society for Steel Treating and the Taylor Society may be mentioned in quite different fields. A second form of co-operation is the joint committee, with life ranging from weeks to years, representing from two to many societies and sometimes including governmental bureaus or educational institutions. Two co-operating organizations which are proving useful and important in promoting research will be described, Engineering Foundation and the National Research Council.

Engineering Foundation

Ambrose Swasey, of Cleveland, Ohio, a leader among the mechanical engineers, eminent for his personal attainments, perceived the desirability of establishing for the engineering societies a fund and an organization to be devoted to research. In 1914, he offered the four national societies of Civil, Mining and Metallurgical, Mechanical and Electrical engineers, $200,000 as a nucleus of the proposed fund. This generous gift was accepted and committed to United Engineering Society, a board of twelve trustees, which had been created by the societies in 1904 and incorporated under New York laws, to hold and administer Engineering Societies Building and Library and other properties belonging to these societies jointly. At the request of these so-called Founder Societies, the United Engineering Society created a department known as the Engineering Foundation Board, to have full power in expending the income of the endowment. The high purpose which Mr. Swasey and those who collaborated with him in organizing the Foundation had in mind has been well stated as being the furtherance of research in science and in engineering and the advancement in any other manner of the profession of engineering and the good of mankind. Subsequently, Mr. Swasey made other gifts, bringing his total to a half million dollars. Assurances of legacies have been received from other persons.

The income of even a half million dollars does not go far in modern research projects. The scale is indicated by the fact that a number of enterprising American corporations have each been devoting annually from a few hundred thousand to three or four million dollars, not to mention the large sums appropriated for research by the Federal government. Nevertheless, by using its resources co-operatively, Engineering Foundation has to its credit a number of useful services. Its first co-operative project can hardly be excelled in results.

In 1916, some of the leaders in the scientific associations and engineering societies realized that the United States could not much longer refrain from participation in the World War. They also perceived that science, technology and industry were proving quite as essential to success in the struggle as were military skill and financial

resources. It was also evident that the three factors must combine in their efforts. Out of these convictions, through the medium of a meeting in New York, came the National Research Council, based on the charter of the National Academy of Sciences given by Congress in 1863, to bring together the scientists of the country for aid to the government in the war then in progress. When organized, National Research Council had no funds. Engineering Foundation had as yet undertaken no project. Its board at once offered the Council an office in Engineering Societies Building and the services of a secretary, devoting all its income for a year, besides funds specially raised. This prompt succor did much toward assuring the permanent establishment and success of the Council. The magnitude of the service thus performed by the engineering societies through the Foundation will appear in part from statements which will follow.

Engineering Foundation is a joint instrumentality of the engineering societies for the support and advancement of research. It is also a bond between scientists and engineers because it maintains its cordial relations with National Research Council. Besides its share in the establishment of National Research Council, the Foundation has to its credit a new form of weir for measuring water, resulting from experiments by Clemens Herschel; A director of hydraulic laboratories in United States of America, recently published; research in determination and measurement of internal stress in metal, now in progress in Columbia University Laboratories; an inquiry into the feasibility of establishing a testing station for large water wheels and other large hydraulic equipment; "Research Narratives", published semi-monthly since January, 1921. The first forty Narratives, recording instructive and interesting incidents in research and invention, have recently been done into a book for use in secondary schools and other educational institutions. In addition, a number of important preliminary investigations have been made, but lack of funds or other reasons have deterred the Foundation from undertaking the projects or carrying them through. Of these there may be named industrial education and training; mental hygiene of industry; organization among engineers; wear of gears.

The Foundation's co-operative projects are still among its most noteworthy; Spray concealment for vessels; fatigue phenomena of metals; directory of research laboratories in industrial establishments in United States of America; highway research; personnel research; corrosion of iron; arch dams; reinforced concrete multiple arches; wood finishing processes, including paints and varnishes; selected hydraulic problems. These projects range through various stages of progress from recent initiation to completion. Besides the National Research Council, the co-operators include industrial establishments, engineering offices, universities and technical societies. In addition, the foundation has been helpful to engineers, industries, societies and other organization in various parts of our own and other countries, and to a few governments in modest ways, for information and suggestions. Copies of the Foundation's Publication No. 4, containing a report for its seventh year and a report on research in Fatigue of Metals will be sent on request addressed to 29 West 39th Street, New York.

National Research Council

National Research Council is a co-operative federation of approxi-

mately eighty American associations concerned with the physical, mathematical and biological sciences and their applications to human welfare through the agricultural, engineering and medical arts. The stage of the world's development in which mankind could depend solely on individual geniuses for advance has been passed. The modern method is more rapid, surer of its path and more likely to succeed. A moment's reflection will convince one that co-operation in civilized communities is now general and inescapable amid modern social conditions although not always formal or organized.

By executive order of the President of the United States, in May, 1918, National Research Council was given permanent standing and the departments of the government were directed to co-operate. The council, however, is not and never has been a government bureau. Its financial support is assured in part by a gift of five million dollars from the Carnegie corporation, of which $1,350,000 is being devoted to a building in Washington. National Research Council also receives and administers funds for specific research projects. Since its organization such funds have totaled nearly two million dollars. In addition, funds for co-operative research projects have been provided, principally by the industries or organizations to be benefited. The council is prepared to act as treasurer for projects conducted under the auspices of its divisions. It is now performing this serviec for several projects of the Division of Engineering. Moneys so contributed are kept in separate funds, separately accounted for and applied only to the purposes designated.

Pending the completion of its permanent building, National Research Council has offices at 1701 Massachusetts Avenue, Washington, for all divisions excepting that of engineering, which has offices in Engineering Societies building, in New York, in order to facilitate co-operation with the societies and Engineering Foundation. The work of the council is performed by an executive board of approximately forty members, by numerous standing and special committees, a small office staff and the organizations of the divisions. The division of engineering aims to carry out the general purpose of the National Research Council in the field of engineering by furthering research and co-ordinating the work of existing agencies.. It seeks to minimize duplication wherever it is wasteful, to collect scattered efforts, to suggest programs for projects, to encourage individual initiative, to make knowledge gained more widely accessible, but not in any case to direct in the sense of dictating. The Division is made up of representatives of 11 national engineering societies, 17 members at large and a representative of the Division of Federal Relations, a total of approximately 40. The Division of Engineering makes itself useful largely through discovering engineering and industrial problems suitable for organized co-operative research; providing for the desired measure of supervision and advice to assure impartiality, authority and completeness for the investigation; serving as a clearing house and effecting correlation with kindred projects or sources of help. For counsel in various matters and for bonds with the societies, the division has an advisory board in each of the several large sectors of engineering, sponsored by one of the large societies.

Nothing can better illustrate the division's purpose and possibilities

than mention of some of its work done. But let it be said at once that the division does not claim full credit for any of the projects listed in its records—only that it has been helpful in some measure, greater or less. Fatigue phenomena of metals have been under extensive examination since the fall of 1919 at the experiment station of the University of Illinois, with the co-operation of Engineering Foundation and the General Electric company. A notable contribution was made to pyrometry by a committee co-operating with the American Institute of Mining and Metallurgical Engineers. Helmets and body armor, economy of manganese, steel ingot practice, deoxidizers for steel, hardness of metals, and uses of tellurium and selenium, are among the important metallurgical problems upon which committees of the division have worked. Large activities in other fields are in the hands of the Advisory Board on Highway Research, the American Bureau of Welding, with its ten active committees, the Molding Sands Committee working with the American Foundrymen's association, the committee on Marine Piling Investigations, enjoying the co-operation of the principal railroads having tide-water properties, several departments of the government, and other owners of marine structures. "Pulverizing," "electrical core losses" and "heat transmission," are titles of other active projects.

Pleasant and useful features of the division's yearly program are the three or four dinner meetings at the Engineer's club, in New York. To these meetings research men and executives of industries are invited and the time devoted to discussion of topics of practical interest to one or more industries, or branches of engineering. Though the division meetings and the meetings of its committees, much information of value passes directly from person to person by word of mouth and in correspondence. The by-products of the division's efforts are perhaps not the least important.

Besides engineering, National Research Council has six other divisions of science and technology: physical sciences, chemistry and chemical technology, geology and geography, medical sciences, biology and agriculture, and anthropology and psychology. Every one of these divisions deals with subjects of immediate interest to engineers. One of the greatest services of the research council is the maintenance of these liaisons among the varied branches of science and technology, to the benefit of each. These divisions provide or suggest suitable specialists for members on committees of the division of engineering, or otherwise co-operate. For example, there are biologists and chemists in the marine piling investigations, physicists in the heat transmission study, and in the fatigue of metals and welding committees, and geologists in the molding sand committee. Geologists have contributed also to highway research. Co-operation of medical men and psyschologists is indispensable in all studies relating to personnel in industry, a subject of great importance to engineers. Engineers and doctors are fellow workers in sanitation.

Furthermore, the council has six divisions of general relations: Federal, Foreign, States and Educational Relations, Research Extension and Research Information. Every one of these divisions has its engineering aspects or elements. The high character of these thirteen divisions and their scores of committees could best be shown by listing the emi-

nent scientists, engineers and men of affairs who constitute their memberships; but such a catalog of hundreds of names would be quite beyond the limitations of this paper. Mention will be made, however, of two divisions in particular, Research Extension and Research Information.

The Division of Research Extension, previously known as the Division of Industrial Relations, has among its functions, assistance in organizing associations for the conduct of research in industry and aid to other divisions, on their request, in planning and financing their projects. It has been instrumental in bringing into existence the American Institute of Baking, the Crop Protection Institute, the American Horological Institute, the board of Trustees for Critical Tables of Physical and Chemical Constants, and similar bodies. It has aided in planning other research organizations in the industries which have not yet been effected, such as the Alloys Research Association and a School of Tanning. It is endeavoring to further research in the cotton, woolen, tobacco. ceramic and other industries. It has managed for the Research Council important exhibits of wireless telephony and of the manufacture of explosives and their by-products. It has aided individual manufacturers with advice and suggestions regarding laboratories, research projects and sources of technical information.

Research Information Service is primarily a general clearing house for information concerning scientific and technological research. The chief purpose is to advance science and productive scholarship by supplying individuals, institutions or companies with desired information concerning results of research and allied activities. Every effort is made to avoid duplicating the work of other informational agencies and to co-ordinate and utilize their resources. It has published a directory of research laboratories in industrial establishments of the United States, a list of scientific periodicals which publish bibliographies and abstracts, a bulletin of funds available in the United States for encouragement of scientific research, and other pamphlets helpful to the promotion of interest in science and its services for engineering and industry. It is compiling and maintaining card lists of laboratories, investigations and personnel for scientific and technical research. The service may be used by any engineer, and even in its present stage of development, has been of assistance to hundreds of inquirers.

Research Information Service has under serious consideration the betterment of means for making scientific and technical information much more quickly, widely, completely and surely available. It would stimulate development of existing worthy agencies and creation of others to fill gaps. The plan under contemplation is not the establishment of a super-abstract bureau, nor the compilation of a great catalog of all scientific and technical knowledge, nor yet the collection of a superscientific library, but, rather, the assembling of information as to the locations and the conditions of use of all the repositories and sources of knowledge within the fields covered by National Research Council, and as to the indexes, catalogs, bibliographies and abstract journals which make this knowledge accessible to scientists and engineers. This division would create and maintain a "master key" or a "switchboard," or aid in organizing and financing a body to have these functions. There is no more needed conservation than that of scientific and technological knowledge. In other words, the proposal

under advisement is to establish an institution, ultimately to become as universally known as the post office, to which one who knows not where to find information on a given scientific or technical subject may apply with the assurance that he will be directed at once to the library, the laboratory, the organization, the governmental bureau, or the person from whom all the information, including the very latest, can be had, gratuitously, or for a proper compensation. Achievement of this purpose requires funds and time and the hearty collaboration of men well informed in the subjects.

The era is passing when from broad conceptions of engineering or from large engineering projects, the human forces can be omitted or "labor" be considered merely as one of the items regulated by market. Especially is this true of the continuing operations of industry and commerce. In many portions of this field of personnel, which comprises the whole gamut from management to unskilled labor, both science and art have made but little sure progress. Too many problems are yet argued on the basis of ill-informed opinion instead of being studied on the surer ground of ascertained fact. In an endeavor to promote the welfare of mankind in this field—than which none is of greater importance—Engineering Foundation and National Research Council after extended preliminary studies, organized the Personnel Research Federation. The object of this organization is the correlation of research activities pertaining to personnel in industry, commerce, education and government wherever such researches are conducted in the spirit and with the methods of science. It is endeavoring to create a clearing house for information in this field, to bring about harmony of effort and to formulate a comprehensive, advantageous plan. The Federation, however, needs additional support and co-operation. In spite of limited resources, it has made a good beginning and counts among its members several departments of government, leading universities, labor organizations, technical societies, and many individuals. It has established the Journal of Personnel Research, with a growing circulation. Its office is in Engineering Societies Building, New York. It has large and unique possibilities for usefulness.

So much for some of the agencies for research for engineering societies. But what are the aims? They are variously stated: the phrases are familiar. For example, "increase of human knowledge," "advancement of the Profession," "development of industry," "national defense." In most instances, these expressions of aim are material or at least intellectual in their implication. So far as they go, they are good; no unkindly criticism of them is even intimated. But man is more than a mechanism of brawn and brain, and this fact must be included in the planning of the engineer. Since art has always been ahead of science in most avenues of human progress—doing things before the fundamental principles were well known—the engineer especially bears responsibility for having put into the grasp of humanity instruments for a material advance which has far outstripped progress in government, jurisprudence, education, religion, and international relations.

Consequently, the possibilities for evil have grown apace with the potentialities for good. Scientists and engineers have been so engrossed in the main in gaining and applying physical facts that insufficient thought has been given to the sociological effects of the knowledge

gained. Enlightenment of the great body of the people in such ways as to make possible the safe assimilation of these facts and their fruits, has been neglected. Poet, priest, politician, jurist, teacher and artist are still too largely entertaining the conceptions and following the precedents of one, two or more centuries ago. Because it is peculiarly the function of the engineer to apply and adapt to the benefit of man the knowledge gained in the natural sciences and the mechanic arts, his studies should henceforth include the deep, subtle, far-reaching effects of his achievements upon social organization, taking into his contemplation not industry alone, and increase of material wealth and comfort, but also the spiritual well-being of all his fellow men. Any good, however ancient, should not be relinquished, but as our knowledge of good extends, these increments should be promptly incorporated into our ultimate purposes and our current practices. Research in science and engineering must be content with no lower aim.

DURALUMIN—ITS PROPERTIES AND COMMERCIAL POSSIBILITIES

By William B. Stout

A MATERIAL one-third the weight of cold-rolled steel yet with the same approximate strength characteristics; a metal which can be heat treated to higher physical properties, yet by process which does not take effect for an hour after treatment; a possibility for much lighter and at the same time cheaper production in certain lines of manufacture—in a few words this is a picture of the future possibilities of the new copper-aluminum alloy known as duralumin.

Receiving its first impetus in the development of aircraft abroad, and particularly by the Zeppelin firm, this metal has been perfected in this country to a point far ahead of the German product, while the work in aircraft of both the airship or lighter-than-air type, and airplane or heavier-than-air machine, has developed processes and methods now applicable to new lines of production.

The new alloy can be rolled into sheets or forged by hand press or power hammer. It can be cast, welded and soldered, while rivets of the same material used with it show new production possibilities on account of the peculiarity of the heat treatment results. Connecting rods have been made of it using the metal itself for wearing surface without anti-friction metal. These have operated successfully in both motor cars and aircraft engines. Worm gears have been used made of "dural" as it is colloquially called, and used in heavy truck service successfully against steel pinions. Timing gears of this metal show new possibilities of both wear and quietness, but the most use has been in structural shapes for ultra-light constructions. The metal itself costs about five times as much as cold-rolled steel per pound. For production work, however, it must be remembered that but one-third the number of pounds is used for the same strength result, while the material, being much easier to work than steel in most of its forms, saves materially on labor tool cost and tool depreciation, and on enough production items so that in many cases constructions can be made cheaper of duralumin than of steel.

The work we have been following has been entirely along the line of minimum weight structures of fairly large size for aircraft work. The saving of a pound in an airplane structure means the addition of a pound of fuel in flight or a pound of pay load so that in aircraft, more than anywhere else, minimum weight is a vital item. However, strength is no less fundamental as an airplane in flight at speed is subject to stresses far greater than imposed on an automobile on the road or any other form of present transport. Imagine having to build a motor truck of 2-ton capacity that could run across a ploughed field at 70 miles an hour without breaking up. This alone would be some engineering problem, yet some modern planes of the bomb-carrying type are designed to do this.

Structures are now being built of duralumin which far exceed former strength figures in wood and yet which are lighter than any previous wood-and-cloth airplane constructions. At present there are in process machines capable of carrying 20 passenger at 2 miles a minute for 5

A paper presented at a meeting of the Society. The author, William B. Stout, is president of the Stout Engineering Laboratories, Inc., Detroit.

hours, and fitted with 600 horsepower in engines, yet the whole machine weighs but the same as a Cadillac touring car. The entire secret of the weight is of course not all in the metal, but it is safe to state that the light weight figure could not have been reached with our present knowledge with any other known material.

Many have preferred steel in their experimental aircraft work on the basis that steel in tensile strength was stronger than duralumin even weight for weight. This is so, but the problem of strength in a structure is not ordinarily of tensile possibilities but of column or compressive strength. For the same weight duralumin has about three times the thickness of even its cold-rolled boiler plate counterpart, and five or six times the section of alloy steels of high tensile. The rigidity of a sheet is dependent largely on its thickness, and while dural is a much more flexible material than steel in equal section, yet with the greatly increased sections used for equal strength, a much greater rigidity is obtained than with steel.

For example, we have produced a rolled section, designed for a maximum column strength, and yet of such shape as to fit production requirements. This section of 0.035-inch thickness of metal in a 19-inch column length weighs 7½ ounces and will support as a column 4 tons plus. If made of steel of high alloy, its thickness would be, so far as tensile requirements go, about 0.009-inch, a too great fragility to be trustworthy in a structure on account of the lack of rigidity of such a thin wall.

Duralumin, as we see it, looks like aluminum except that it takes a high polish. The polish in ordinary atmospheres is permanent, the metal being noncorrosive to a high degree. In the tempered state it is almost impervious to salt spray, though in the annealed form salt water affects it. The chief difference between this and previous aluminum alloys is its property of having its physical characteristics materially changed by proper heat treatment. This heat treatment in itself acts differently than with other metals, leading to some peculiar production possibilities. Like all new things, this metal with its peculiar properties has certain assets and define liabilities, but even its liabilities, in some cases, can be turned to profit, provided the structures made of the metal are designed to fit the peculiar requirements of the alloy.

The most marked difference in the metal is that the change in physical properties following heat treatment is not instantaneous but arises gradually to a maximum after about four days, and during this period not only is the tensile strength increased, but the elongation may also increase. More than this, the metal in its heat treated form can be reheated and softened for passing through mechanical processes not of too violent a nature, and at the end of one hour come back to its original tempered characteristics. The fact that the extreme properties of the metal are not reached immediately, as in most metals, is of great advantage commercially, as will be explained later.

The heat treatment of the metal, or tempering, as it might be called, consists of heating the metal to 920-940 degrees Fahr. for from 7 to 30 minutes, the time being governed by the amount of metal in process. The material is then quenched in boiling water. It is then removed from the quenching bath and worked upon as soon as possible. In from one to two hours' time enough hardening will have taken place so that it will be difficult to work the metal. Where the time involved in making up the

piece does not exceed one hour and where the bendings or hammerings are not too severe, this process is a thoroughly feasible production method.

This allows us in our airplane work, for example, to heat treat a coil of sheet metal in a bath of sodium and potassium nitrates, quenching in an adjacent tank of boiling water, and uncoiling the sheet or strip, start it immediately through the rolls which form it into the shape desired, having the complete process over, and the spar ready for ageing within 20 minutes from the beginning of the operation.

It is not the author's intention to go into any of the technical details or metallurgical study of the scientific side of this new alloy, but rather to point out the numerous possibilities opened up by its use and to describe and explain some of the results and processes now being obtained with duralumin, primarily in aircraft work. It will be stated only that the metal itself is nothing other than a copper-aluminum alloy, the

COMPOSITION AND PHYSICAL PROPERTIES OF DURALUMIN

Chemical Composition

	Per cent
Copper	3.50-4.00
Magnesium	0.20-0.75
Manganese	0.40-1.00
Aluminum, 99 per cent pure	Balance

Physical Properties

Specific gravity	2.80
Weight, per cubic inch	0.102
Melting range, degrees Cent.	540-650
Compressive strength tempered, pounds per square inch	44,000
Shear value tempered, pounds per square inch	30,000
Tensile strength tempered, pounds per square inch	50,000-60,000
Elongation tempered, per cent	16-20
Modulus of elasticity, pounds per square inch	10,600,000
Coefficient of expansion, per degree Cent.	0.0000226
Yield point, pounds per square inch	30,000

copper running about 4 per cent, and some magnesium, but with zinc as the most detrimental component. For this reason, duralumin is made only from the purest 99 per cent aluminum, so that the impurities in each of the alloys from which the metal is formed will not build up a detrimental quantity. It is the inability of the Germans to obtain pure aluminum which has hindered their duralumin alloy from equaling the figures obtained in every day production from the American product. The composition and physical properties of duralumin are shown in the accompanying table.

The metal itself, however, was developed in Germany from an original French laboratory development. The first real commercial use to which it was put, so far as the public was concerned, was in the metal ships of the Zeppelin company. One of the reasons for the slow development of the Zeppelin, aside from the problems of airship design itself, was the necessity of developing the metal along with the structure, and it is certain that the material, unless rightly handled, has many idiosyncracies.

In the early metal, considerable trouble was had with corrosion and with sheets, seemingly without reason, granulated; and until the properties and difficulties were worked out, structures built of the material were

more or less uncertain and required frequent inspection. This is still true in thin gages which are not carefully heat treated, but with pieces of any real section corrosion is now an almost unheard of thing.

In the following outline the author will give merely experiences with the present liabilities of the material and things to be watched out for in its use, but in criticizing he would, at the same time, state the belief that duralumin and derivatives which will spring from it will form undoubtedly the mainstay of all future lightweight developments in automotive and kindred structures, and that the use of this metal will grow by leaps and bounds as its marvelous advantages in both structure and production become generally known and understood.

The main trouble found with duralumin is more or less similar to the problem met in other alloys, that is, the presence of impurities in the ingot, or air bubbles, small in their original forms, but which, when worked out and forged into thinner sections, developed into serious defects. Most of our material is of 0.035-inch stock, so that a small speck of dirt can make a serious flaw in the metal sheet and a small air bubble can make a considerable pipe in the center of the sheet, almost impossible to find except by microscopic examination.

Most of these flaws do not show up until after the rolling as in the case of an intricate chord section. In this case, the greatest stress on the metal in putting it through the rolls is at a hidden point, so that to inspect these spars or chord members a dental mirror is used with a high light, and the surface carefully examined. Frequently a hole as small as the point of a fine needle can be opened up into a flaw 5 inches long—a sort of stratification of the metal, resulting from original ingot impurities.

At the beginning of our work spar rejections, for this reason, ran as high as 80 per cent, this gradually being reduced, and it seems possible in the near future that the rejections will be normal. In all these sections there has been no attempt at drawing the metal, but merely bending it, as any attmpt to draw the metal results in an extreme number of rejections through cracking. It is peculiar that these cracks may not appear until a number of hours after the piece is made, so that after rolling, four days is allowed to elapse before parts can be inspected for cracks or flaws, or before any piece is allowed to be put into the actual airplane structure. In the design of the rolls, great care must be taken also against too great a degree of draw between annealings, and that all radii are of sufficient amplitude for the metal.

The great drawback of the material as we are using it at present, is the presence of ingot flaws, rolled out in the sheet which lead to this high rejection cost. When this is cured it can be said that the experimental stage of duralumin is over. As soon as quantities of the material are demanded, rolls can be put in for greater widths of sheet than at present available—16 inches being now the best obtainable—and tubing and other structural forms can be made available.

It is believed that this material, and developments from it in better alloys, eventually will be more universally used than steel for structural requirements. Its use in aeronautics is already definitely established, new as its use is, and the all-metal plane already is given preference to the older types. It is believed we will next see it in motor cars, at a saving of over half the weight, and in boats and busses, street and railway cars, bridges and girders. For the time being, however, it is a material

to watch and study, and to make use of conservatively in conservative lines of engineering, but in ultra-progressive fashion in those industries like aircraft where reduction of weight is a vital element of safety.

Discussion of Mr. Stout's Paper

MR. THUM: The number of rejections that you gave, is that the number you got when you started out?

MR. STOUT: We got one good spar out of about five.

MR. McCLOUD: You spoke of the possibility of soldering duralumin. About how does it compare with aluminum as to the ability to solder it readily? Is it much more easily soldered than aluminum, or does it present much the same difficulties?

MR. STOUT: It presents about the same difficulties. The only places where we have considered soldering at all is for waterproofing joints. Naturally a soldered joint will not pull anywhere near what the duralumin would, but we have soldered adjacent to a riveted joint in order to waterproof. It is fairly easy to solder.

MR. PORTER: Is the material suitable for use where it is liable to vibrate? I would like to know whether or not it has a vibratory stress.

MR. STOUT: Like other metals, that is a question of design. Anything designed of too little strength will be affected by vibration in proportion, but the vibration tests that have been conducted by the navy and also by the army show a little higher resistance to vibration than cold-rolled steel.

MR. STAFFORD: Have any experiments been made along the line of making seamless tubing?

MR. STOUT: Yes, the Germans are practically the only ones who have done it, due to the fact that the process involved requires a great deal more power behind it than the steel tubing. You can't use the same machinery and produce it.

MR. STAFFORD: It can be done?

MR. STOUT: It can be done. The tubing can be purchased in Germany.

FEDERAL AND STATE RESEARCH AGENCIES

By W. M. Corse

NOTHING remains continuously the same. Hence, there is no limit to research. The non-thinking man may believe that available knowledge comprises nearly all that may be known, but the thinker recognizes that he lives in a world which we understand but imperfectly. Our own country, as well as the whole world, saw the national importance of science and research in the early days of the great war. Problems arose immediately that were soluble only through scientific research. And Germany gave us evidence of her appreciation of this fact by her high state of preparedness, which admittedly was due to the fact that for nearly half a century she had been a nation given to investigation in a great variety of little explored subjects, but which made her a giant in strength in the face of the Allied Powers.

The United States, however, was not without its scientific research agencies. But these have always been cramped in view of their economic importance. When one single disease of wheat—the black stem rust—will destroy two hundred and eighty million bushels of wheat in a single year in the United States and Canada, and the boll-weevil takes its toll of millions of acres of cotton, the complaint of expenditures in the Department of Agriculture by the politicians seems rather stupid to an intelligent man who sees these same politicians voting away millions for less useful purposes. Figures just made public show that from a point of loss in production of cotton through all causes, 1921 was a record year. The estimated production of cotton in the United States aggregates 18,666,000 bales. There should be added to these figures 10,712,000 bales, which were not produced for one reason or another, for which the boll-weevil was responsible for 6,277,000 bales in one year alone. When we consider that the average export of cotton for ten years was 7,456,000 bales and our domestic consumption was 6,396,000 bales we can begin to appreciate the actual loss in dollars yearly from the presence of this pest.

Although you may already be aware of it, it might be well to repeat that in 1920 the budget showed an expediture of 1 per cent by the federal government for research, education, and developmental work as against 92.8 per cent for obligations arising from wars and expenses of the War and Navy Department and Shipping Board, 3 per cent for public works and 3.2 per cent for primary governmental functions such as Congress, the Presidency and the various departments. Just about 50c of the $50 expended per capita per annum by the federal government goes for research, education, and developmental work.

What are the government agencies for research, and what do they do? Necessarily in the brief time at my disposal I can but look at these in a cursory manner. As a general statement it may be said that in each department of the government there is some research function. Even Senators and Congressmen are supposed to be acquainted with facts, and some of them do make an effort to get these. The Department of State has its Division of Foreign Intelligence and its Division of Political and Economic Information. The Department of Justice, of course, is a department where investigations in many ways go on. In

A paper presented before the Detroit Convention Research Symposium. The author, W. M. Corse, vice chairman, Division of Engineering Research, National Research Council.

the Department of Labor there is the Bureau of Labor Statistics, which collects information on the subject of labor, its relation to capital, the hours of labor and the earnings of laboring men and women, and the means of promoting their material, social, intellectual and moral prosperity. The Children's Bureau was established by Act of Congress to investigate and report upon all matters pertaining to the welfare of children and child life. And the Women's Bureau has for its function to report upon all matters pertaining to the welfare of women in industry, and based upon such investigations to formulate standards and policies which shall promote the welfare of wage-earning women, improve their working conditions, increase their efficiency and advance their opportunities for profitable employment.

The Bureau of Efficiency is a scientific research bureau along economic and personal lines to improve the business methods of various branches of the government service. The Bureau of Education has for many years been engaged in statistical and other research that would give a record of the educational work of the country. Even the Federal Reserve Board and the Railroad Labor Board have functions of research. The former has a special Division of Analysis and Research, its purpose being to determine the per cent of the total expenditures going toward food, rent, clothing, etc., of a typical family or individual in each salary group in order to give proper weighting to the price changes reported by the United States Bureau of Labor Statistics at intervals of six months. The Railroad Labor Board makes studies, of course, of conditions upon which it bases its decisions. These are merely typical of general research work by Federal agencies.

But the group of men before me is more interested in the more fundamental scientific research being carried on by the government in what are distinctively scientific bureaus. The most widespread work is that of the Department of Agriculture, under which we find such bureaus as those of chemistry, entomology and plant pathology, for example. These are distinctively scientific investigation bureaus, though of course, a certain amount of adminstrative and control work is done by them. The Bureau of Chemistry, for instance, sees that there are no contraventions of the Food and Drugs Act. The Insecticide and Fungicide Board has charge of the prevention of adulteration and the wrongful labeling of remedies for the control of plant diseases and injurious insects. The Forest Service is not statistical in its work, but engages in definite research work towards the preservation of the wood of the country and its better use. The Bureau of Soils makes a scientific study of all conditions of the soils of the country. And the Bureau of Public Roads is engaged in developing through definite research and test work the best kind of road used under a given condition. The work of the Department of Agriculture is so broad that I am not attempting to more than indicate part of what it is doing.

The Department of Commerce is likewise engaged in research work. Through its Bureau of Fisheries it is seeking to understand the best conditions for maintaining and increasing the value to the nation of a great natural food product. The Bureau of the Census makes, of course, statistical researches which have varied uses. The Bureau of Foreign

and Domestic Commerce aids American industries through its investigations of countries abroad and opportunities of the extension of American commerce.

The Bureau of Public Health is one of the most important of the agencies doing work of research and education. It is in the Department of the Treasury. It does not only maintain supervision of incoming vessels to prevent the introduction of disease and acts in other ways for similar purposes, but carries out scientific research to develop methods for preventing the spread of the disease.

But there are three branches of government service that appeal particularly to you men whom I am addressing, for these agencies have special concern, among their other functions, with investigations and researches in steel. These are the Bureau of Mines of the Department of the Interior, the Bureau of Standards of the Department of Commerce, and the War and Navy Departments.

The research work in the Army and Navy is chiefly the work of the ordnance departments, the Air Service, the Signal Corps and the Chemical Warfare Service. As a sample of the work done in the Ordnance Laboratory at Watertown Arsenal, one might mention such investigations as the following:

An examination of castings having different manganese content;

An examination of high manganese steel castings to determine the chemical composition and microstructure of this steel;

Experimental heat treatment of cast steel to determine the effect on the physical properties, including the Charpy impact strength of three standard heat treatments applied to cast steel in the Arsenal foundry;

Investigation to determine the effect of phosphorus upon the properties of cast steel with particular reference to the shock strength;

Compressive tests of copper cylinders for pressure gages.

But the Bureau of Mines and the Bureau of Standards are the agencies of the government which go more deeply and widely into investigations which we think of as strictly fundamental research. The work of these Bureaus overlaps to some extent, but on the other hand each has its specific work. The Bureau of Mines, according to its organic act, is "to make diligent investigation of the methods of mining, especially in relation to the safety of miners, and the appliances best adapted to prevent accident, the possible improvement of conditions under which mining operations are carried on, the treatment of ores and other mineral substances, the use of explosives and electricity and other inquiries of technologic investigations pertinent to said industries."

For a number of years Dr. Gillett, and his co-workers of the Ithaca Field Office of the Bureau, have been carrying on work on the experimental production of alloy steels. These included those steels containing zirconium, titanium, uranium, boron, and cerium. They found that when the raw material used is sufficiently low in sulphur and phosphorus to obviate the making of refining slags, and straight melting, analogous to crucible steel practice, is done, the making of special alloy steels in 50 to 100 pound heats, to chemical specification, is relatively

simple in a 50-kilowatt indirect-arc furnace after the behavior of the ferroalloys to be used is known, and the behavior of such alloys can be conveniently studied with the furnace.

One of the objects of this investigation was the recovery and segregation of the different alloying elements. Some of the steels prepared are of rather unusual composition, many being nickel steels high in silicon. No general conclusions are drawn as to the value of the various alloying metals above mentioned in commonly used types of steels. The results of the physical tests so far obtained on steels of which these elements are present in appreciable percentages have not in general been promising. In plain steels of low carbon content to which less than one fourth of one per cent of zirconium has been added, it seems that zirconium may have a beneficial effect, especially on notched-bar impact tests. Even in small ingots noticeable segregation of uranium, or cerium generally appears when over about one-half of one per cent of the first, or about one-third of one per cent of either of the two latter is present in the steel. These readily oxidizable elements are best added in the ladle, or to the furnace immediately before pouring. In remelting scrap containing these elements, they will be almost wholly lost, even in electric furnace melting. Uranium and zirconium alloys used to introduce these elements into steel should be as free from carbon as possible. Alloys of zirconium with silicon or nickel, or both, give fair recoveries of zirconium, but no ferro-zirconium tried does give recoveries of zirconium. Titanium does not segregate as readily as zirconium, and its recovery from the ferroalloy is higher; but in large amounts it is likely to segregate. The addition of a more readily oxidized element, such as zirconium, seems to help on the recovery of titanium. Although these elements are readily oxidized, none of them appear to be as efficient as aluminum or vanadium in degasifying "wild" steel. Dr. Gillett, in his work, made no special study of the use of small amounts of these elements as scavengers only. Boron is almost quantitatively recovered when added at the end of the heat, and may be added at the start of the heat without great loss. In the amounts studied up to three-fifths of one per cent, no appreciable tendency to segregation was noted.

The Ithaca Office has also studied molybdenum steel, especially with reference to whether molybdenum steel has properties which makes it a possible substitute for vanadium steel, or whether it has any properties of its own which make it valuable. No results of the tests on molybdenum steel are yet available to the public. In the determination of the physical properties of these steels, the results indicate the necessity of studying the properties of "clean" metal versus "dirty" metal. In other words, the study of the effect of included solids in the steel. The results of the physical tests show that in certain cases at least a clean steel will give tests from 100 to 1000 times as great on Upton-Lewis machine as a dirty steel of the same composition.

At the present time the Ithaca Field Office is concerned in tabulating and plotting tensile, impact and repeated impact tests on molybdenum, cerium, and other alloy steels obtained during the last two years. The endurance results so far obtained will be similarly dealt with shortly. It is hoped that very soon experimental work will be carried on to determine the affect of inclusions in steel alloys and also in brasses and

other copper alloys. These are just by way of samples of the important research work that is being done by the Bureau of Mines.

The Bureau of Standards is more concerned with the development and maintaining the standards of length, mass, volume, temperature, electrical and optical measurements and in the preparation of standard chemicals. Its name itself characterizes the prime reason for its being. A very large amount of work is done for the army, navy and other governmental departments and for state institutions.

The Bureau is much broader than the metal field, dealing with textiles, leather, rubber and a great variety of products. In the field of metallurgy it concerns itself with experimental research and the acquirement of knowledge in fields relating to products metallurgy as distinguished from process metallurgy. But in mentioning some of the important problems which have engaged its attention during the past year I will confine myself to the working of the Metallurgical division, and even here can but touch upon its program. A full report of last year's work will be released. I understand, in November. Particular attention has been given to the study of the methods of analyses for gases in metals. As you all know this is one of the most baffling subjects in all the fields of metallurgy. The main object in view has been to devise methods for the elimination of the harmful effects of gases in metals. A study was also made of deoxidation processes in steel and iron manufacture. Thermal stresses in chilled iron and steel car wheels is a study of particular interest to the railroads; and attention has been given also to the effect of using titanium in rail steel manufacture. The division will now give attention to methods of abrasion testing, having recently completed its first program relating to bearing metals. Under a joint committee an investigation has been carried out on the effect of sulphur on several grades of steel, and a preliminary publication has been issued dealing with the relation of the sulphur content to the properties of rivet steel. Other publications soon to appear will give results of a study of the rolling characteristics of medium carbon steel, the properties of pure alloys of iron, carbon and manganese, and the testing or wrought iron. Investigations started are the corrosion of rust-resisting chromium and other steels, the preparation of platium alloys and the comparison of the cutting qualities of high-speed steels, and, through the instrumentality of joint committees, investigations relating to gage steels, mine drill steels, molding sands; welded rail joints and thermal stresses in steel wheels. During the past year the division did further work with magnetic methods for determining critical ranges in steels with varying degrees of success, and tests were made of made of quite a number of commercial carbon and alloy steels and metals of special composition throughout the range 20 to 550 degrees Cent. Tests of the effect of heat treatment of some of the newer alloy steels were also continued. But here again I must state that it is quite impossible to even sketch in the time allotted for this paper a tithe of the work that is done at the Bureau of Standards.

Before considering briefly the research work in the states it may be well to say that the word "research" is often used by the average man with much less meaning than the scientist gives to it. Simple investigation and routine testing often pass for research. According to the scientist's definition of research there is not a great amount of research

work being done by the state governments. Most of it is in the agricultural colleges. A number of states are also interested in geological investigations and others have fish commissions, but the condition in the great majority of states is by no means what it should be.

The National Research Council, through its Division of States Relations, has been securing data about the facts of the case, and I may refer to reports which have been made to it upon surveys of Illinois and California, as showing some of the things that are lacking. These two states are among the foremost in educational and research work. The report of California says that the administrative agencies of the state engaged to a limited extent only in the work of scientific research. They are primarily concerned with administration of previously ascertained standards, having either not the time, or facilities, or the inclination to submit their processes to the test of systematic reinvestigation. It was stated by an official of the California Department of Agriculture, one of the very few agencies in which research proper is carried on, that its work was "90 to 95 per cent administration; 5 to 10 per cent research." Great reliance is placed by nearly all the state agencies upon the institutions of higher learning of the state, especially upon the University of California.

In Illinois the research agencies of the state are the State University, the Bureau of Tests of the Highway Division of the Department of Public Works and Buildings, the Geological Survey, Water Survey, the Natural History Survey, the Psycopathic Institute and the Institute for Juvenile Research.

The following recommendations were made by Dr. Leonard D. White, of the University of Chicago, who made the survey for the National Research Council of the conditions in Illinois.

1. Research should be recognized as a specialized function and clearly differentiated from administration.

2. The State University should be recognized as the central research agency of the state government.

3. Greater opportunity to develop a prefessional esprit de corps should prevail.

Affiliation with the University would work in this direction. Closer contact with the Illinois Academy of Science may likewise be recommended. A professional esprit de corps would be stimulated by the establishment of professional associations with regular meetings at which attendance should be expected and for the expenses of which the state should provide.

4. The co-ordination of research should be further organized. Such co-ordination might be brought about by the establishment of a state council on scientific research. This council should be composed of the heads of the research departments of the State University, the heads of the scientific bureaus and agencies, representatives of the departments of administration and of finance, and representatives of industry so far as relevant to the purposes of the council.

5. Special attention should be given to popularizing the research function in order to lay the permanent foundation for legislative and financial support.

6. The scientific personnel should be placed on a permanent nonpartisan basis and should be free from administrative duties. This result would be attained by consolidation or affiliation with the state university. All requirements of residence in the state as a prerequisite to appointment should be abolished. The salary scale should be the equivalent of that maintained in the state university for persons of similar professional attainments.

In most states there are the usual scientific agencies, boards or commissions of conservation, forestry, fish and game, public health, mines, the geological survey, a department of agriculture, etc. Many of these are provided with facilities which enable them to engage actively upon research problems connected with their administrative work. But there is a possibility for much greater development of the research function in the departments of our state governments.

Primarily the matter seems to involve a clearer understanding than we now have of the sources to which the scientific departments of a state government ought to look for research assistance in meeting their administrative problems. In most states practically all of the agricultural research work of the state is done by the state agricultural college, working in close co-operation with the federal Department of Agriculture. The state university also is a great resource for research and should be so related to the state government as to permit the utilization of its reseach capacity for the good of the state without interfering with the proper educational functions of the institution. We should be in position to insist on increased support or research on the part of the state government if it could be said that all of the research resources of the states were so co-ordinated as to permit of their utmost legitimate utilization for the commonwealth and if we could have a clear recognition of the type of scientific work which ought to be undertaken by the various agencies and the type of work which can best be carried on cooperatively with the federal government or jointly with other states.

The importance of real fundamental research work to the nation is being more widely appreciated, but is not yet understood as it must be if we are to maintain our place among the nations. The fact is that in every manufacturing country the importance of research in relation to industry has come to be realized more strongly than ever. I am speaking not of the scientist's outlook, which essentially embraces the fields of research, but rather of the recognition of the practical value of research by manufacturers and by the thinking public generally. Nations abroad are establishing research institutions. Germany's preparedness both for war and for industry has opened the eyes of big business men. Dr. J. J. Carty, vice president of the American Telephone and Telegraph Company said in his presidential address to the Institute of Electrical Engineers in 1916, "By every means in our power, therefore, let us show our appreciation of pure science, and let us forward the work of the pure scientists for they are the advance guard of civilization. They point the way which we must follow. Let us arouse the people of our country to the wonderful possibilities of scientific discovery and to the

responsibilities to suppport it which rests upon them, and I am sure they will respond generously and effectively."

Other prophets have called us to follow the same course.

What Is The Matter With The American Railroads Today?

(*Concluded from page* 184)

railroads, and during the strike, will certainly be recorded as extraordinary. There is, in my judgment, no other business that could survive as the railroads have, under the attacks that have been centered upon them.

The relief lies in less regulation and in removing the railroads from politics. Repeal the useless and extravagant regulatory laws that exist only for the purpose of making political jobs for the faithful and for the parasites of union labor. The people should give a mandate to congress that will compel, forever, the demagogues, to keep their bungling and paralyzing hands off transportation and the great industries of the country.

ADVANTAGES OF THE FORGED MILLING CUTTER

By William G. Calkins

AS A result of the rapid strides which have been made in the past few years in increasing shop efficiency and production, a demand has arisen for a superior grade of milling cutter; one which is able to withstand the highest rates of speed and feed without excessive deterioration, thereby removing metal at the lowest possible cost per unit.

The beneficial effect on steel conferred by the proper forging and mechanical working at correct temperatures is well known. It must be borne in mind, however, that the forging of high speed steel is an operation requiring a high degree of experience and ability and the operation cannot be compared with the ordinary drop forging of low carbon alloy steels similar to those used in automobile construction.

By the term "high speed steel" we refer to a steel of the high tungsten, high chrome type which has been adopted by the majority of the reputable tool manufacturers as the material most suitable for the manufacture of the highest quality of cutting tools. The following are excellent minimum and maximum limits for the principal alloying elements in such a steel:

	Per cent	
	Minimum	Maximum
Carbon	0.65	0.75
Tungsten	17.00	19.00
Chromium	3.50	4.50
Vanadium	0.75	1.50

This specification does not preclude the possibility of making tools which will perform satisfactorily from the so called low or 14 per cent tungsten steels for certain operations, but where the utmost limits of endurance are required in drilling or milling operations the 18 per cent tungsten steel invariably will prove to be superior. The average performance of all the 14 per cent tungsten steel drills which have been tested in the plant with which the author is connected has been from 60 to 75 per cent of the maximum obtainable from drills made from the high tungsten type. Conditions in planing operations are somewhat different and some of the largest machine shops in the country favor the low tungsten steels for this type of service.

Two methods of manufacture are to be considered in making high speed milling cutters: 1. Direct cutting from bar stock; and 2, upset or forged method. Before attempting to outline the advantages of a forged cutter as compared to a cutter made direct from the bar stock, some consideration must be given to the process of manufacture of high speed steel with special reference to the internal structural condition.

High speed steel whether made by the crucible or electric process is cast in the molten state into iron ingot molds. The side of the ingot will ordinarily vary from 3 to 12 inches square with rounded corners and made slightly tapering. It is essential that the ingot be cast as nearly perfect as possible and special attention must be given to the prevention of excessive pipe, blowholes, segregation of certain constituents, etc. Piping is the term applied to the cavity which forms in the top portion of

---

A paper presented before the Society. The author, William G. Calkins, is Metallurgist, Detroit Twist Drill Co., Detroit.

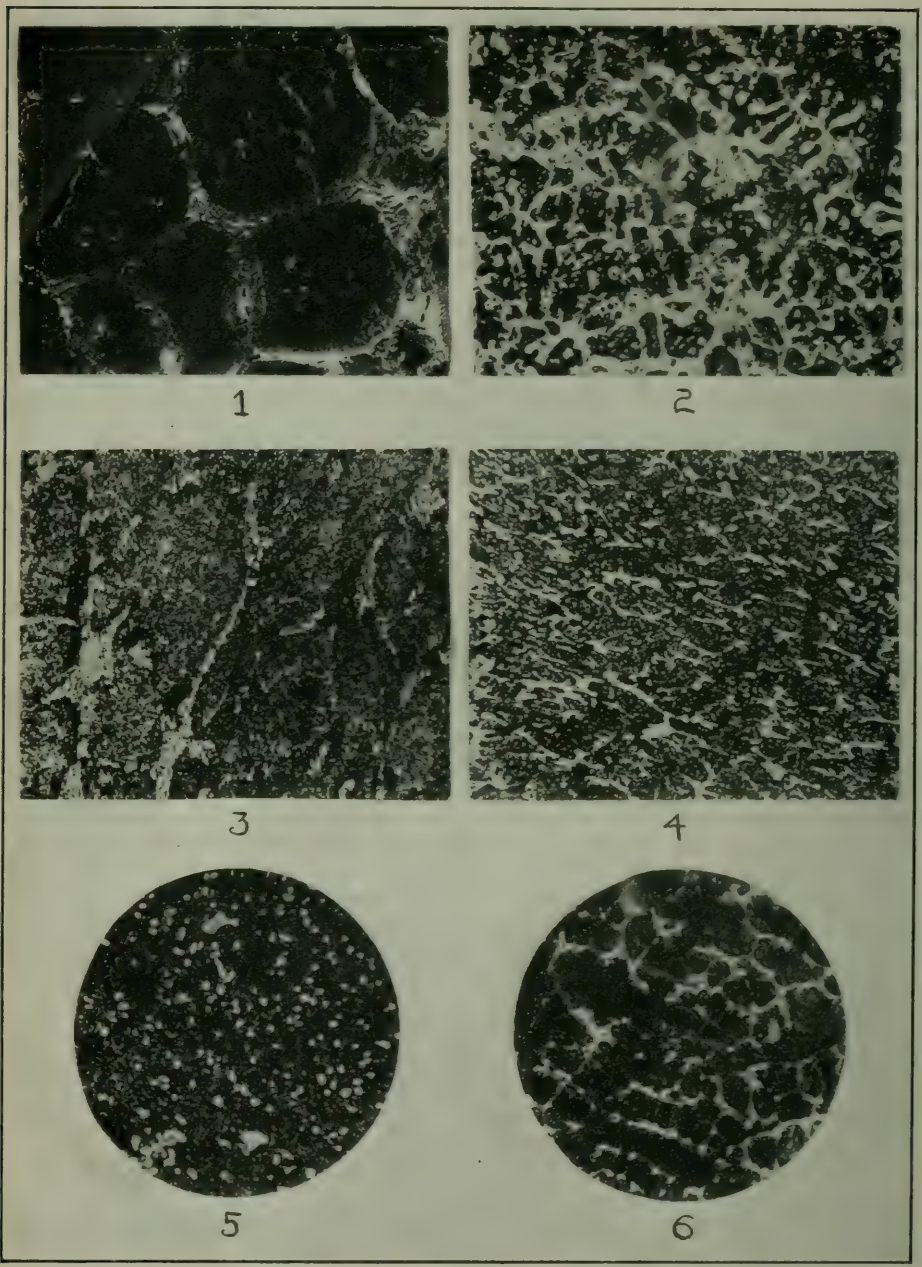


Fig. 1—Photomicrographs of a high speed steel ingot as cast. X 250. Fig. 2—The same as Fig. 1 but X 50. Fig. 3—Photomicrographs of a high speed steel billet. X 250. Fig. 4—The same as Fig. 3 but X 50. Figs. 3 and 4 show the effect of reductions as compared with the ingot structure of Figs. 1 and 2. Note the remnants of carbide envelopes. Fig. 5—Photomicrograph of $\frac{7}{8}$-inch annealed high speed steel bar stock. X 250. Fig. 6—Photomicrograph showing center of a 6-inch round. X 100

the ingot due to shrinkage as the ingot cools and solidifies. The central portion of an ingot, due to the fact that it is last to solidify, always contains the least desirable structure, being more coarsely crystalline than the outer portion and also subject to segregation of impurities, slag, etc.

When a section of high speed steel is polished, etched and observed under the microscope highly magnified, it appears to consist of at least two separate and distinct components; one of which is dark in color and the other light. Figs. 1 and 2 illustrate the structural condition in the interior of an ingot as cast. Attention is called to the coarse crystalline condition and so called "carbide envelopes" or cellular structure. Steel showing this structure is not suitable for use in cutting tools. These carbides are probably mixed complex tungstides and carbides of iron, chromium and vanadium, concerning which the exact chemical formulae are not definitely known.

The high speed ingot is then annealed, primarily to assist in emulsifying the cellular structure and to remove internal strains caused by cooling and contraction; also to enable drillings to be taken for purposes of analysis. The next operation is the removal of surface defects such

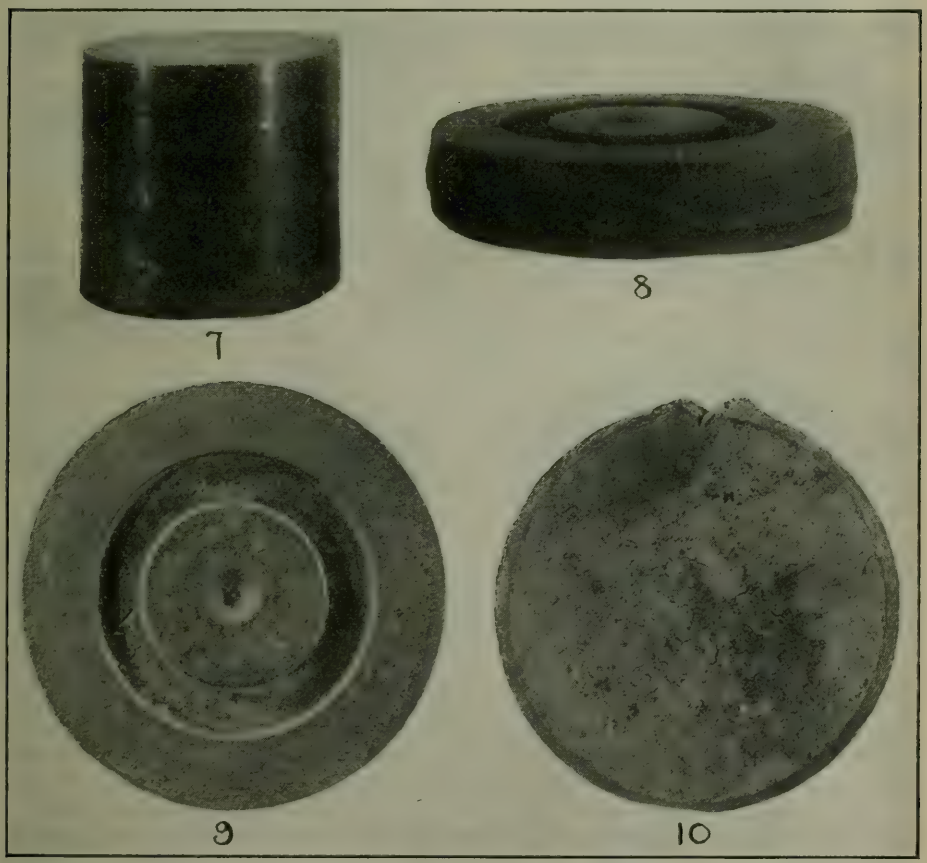


Fig. 7—A piece of round stock ready to be forged into a cutter blank. Fig. 8—The blank as it appears after the forging operation. Fig. 9—A finished high speed steel milling cutter blank. Fig. 10—Forged high speed steel disk showing radial crack developed by hammering between flat-faced dies

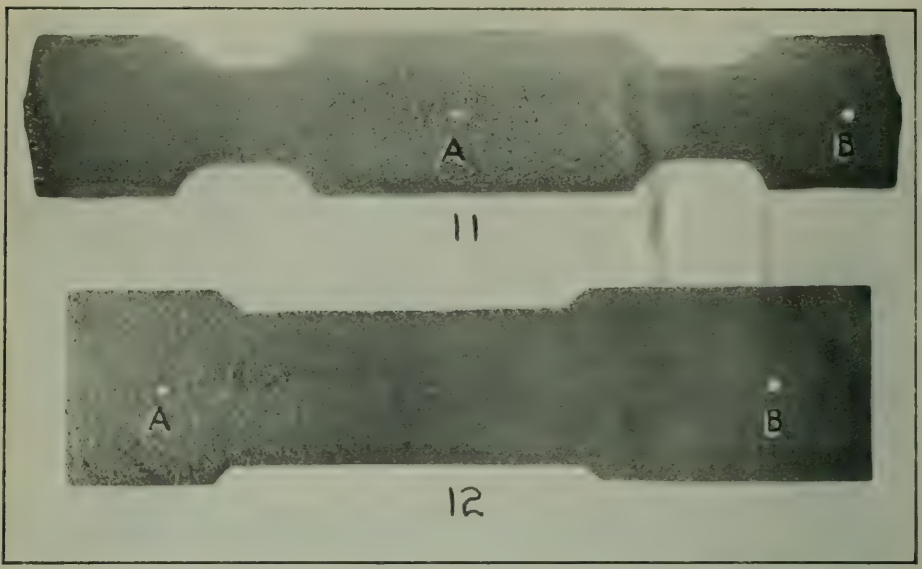


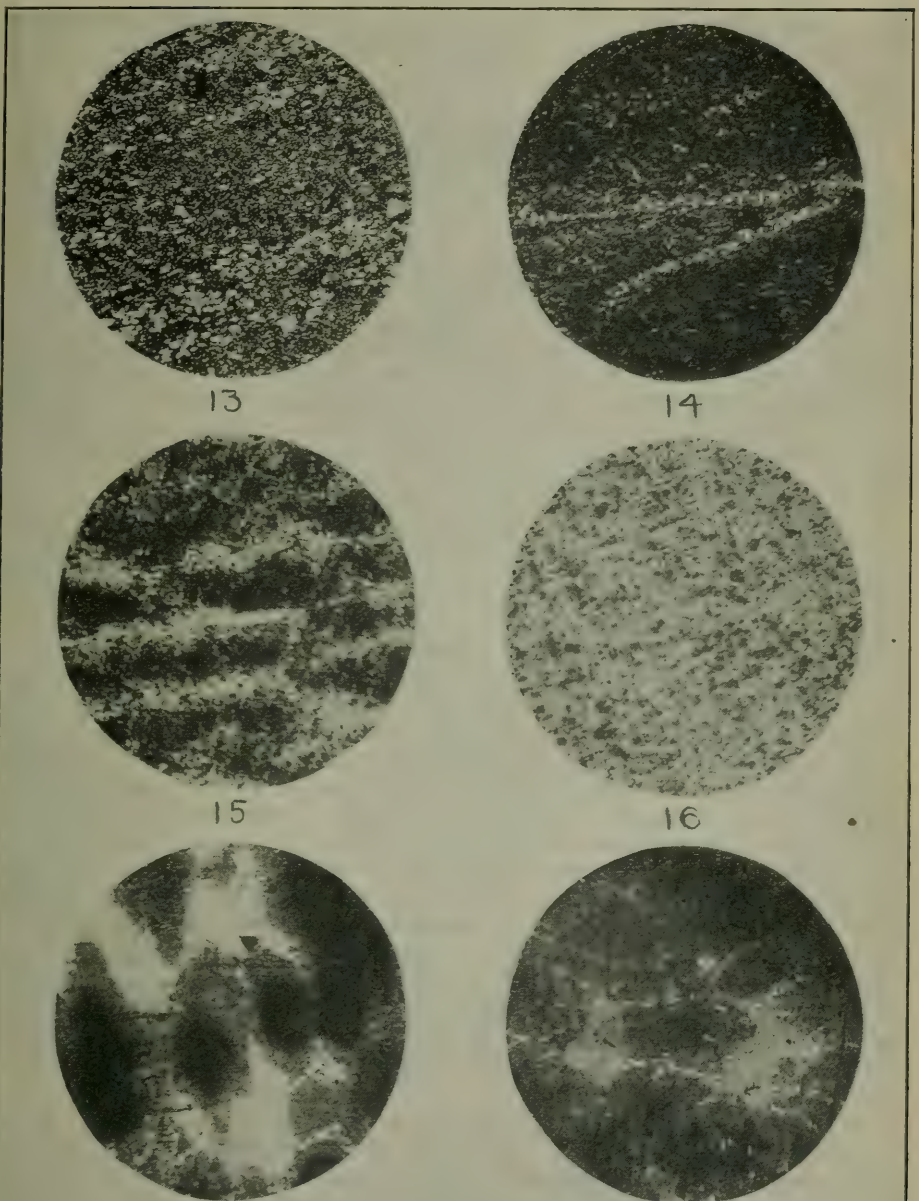
Fig. 11—Cross section of forged high speed steel milling cutter. Polished and etched to bring out structure. Note ring of fine grained dense metal extending around edges of teeth and more open grain toward the center. This is actual direct photograph without retouching. Photomicrographs of points *A* and *B* are shown in Figs. 15 and 16 respectively. Fig. 12—Cross section of high speed steel milling cutter made from bar stock. Note coarse crystalline condition showing dendrites or pine tree crystals indicative of lack of sufficient reduction and mechanical working of the steel. This structure is not desirable for cutting tools. Photomicrographs of points *A* and *B* are shown in Figs. 17 and 18 respectively

as checks, blowholes, slag inclusions, etc., by grinding them out with portable grinding machines. The annealed and ground ingot is reheated and hammered or cogged under a steam hammer and an amount equal to about 20 per cent of the ingot weight is cut from the head or pipe end in order to eliminate difficulties due to the shrink cavity being rolled into bars, thus causing hollow centers or seams.

The effect of the hammering and reduction is to break up the coarse structure, refining and distributing the carbide and tungstide particles throughout the mass of the steel. The ingot after cogging and cropping is technically known as a billet. The structure of a high speed billet is shown in Figs. 3 and 4.

The billets are then annealed and ground in the same manner as the ingots and delivered to the hammers or rolls, as the case may be, for final finishing to shape and size. After hammering or rolling, the bars are again annealed and are ready for the market.

The microstructure of a piece of properly worked annealed high speed steel is shown in Fig. 5 which is a cross section of an annealed 7/8-inch round bar. Here the particles are small, well broken up and uniformly distributed, indicative of correct conditions of manufacture and an ample amount of reduction in size from the ingot. This illustrates the desirable structure for high speed steel. Large rounds, for instance from 4 to 9 inches, invariably show a marked lack of uniformity in structure and the central portions frequently retain the raw ingot structure as result of insufficient reduction. The condition existing in the center of a 6-inch round is shown in Fig. 6 in contrast to the internal structural condition existing in the small bar stock where the percentage of reduction has



Figs. 13 and 14—Photomicrographs showing carbide segregation in high speed steel bar stock. Figs. 15 and 16—Photomicrographs showing structures corresponding to points *A* and *B* respectively of forged high speed steel milling cutter shown in Fig. 11. X 50. Figs. 17 and 18—Photomicrographs showing structures corresponding to points *A* and *B* respectively of high speed steel bar stock milling cutter shown in Fig. 12. X 50. Note the difference in grain structure of Figs. 15 and 16 and Figs. 17 and 18

been ample. In this condition lies the greatest advantage in the use of the forged cutter.

Little explanation is required to make clear the process of manufacture of cutters from bar stock. The material as received, which is only a small fraction of an inch over the diameter of the finished cutter is cut to the required length and the operations following are essentially milling the teeth to the required shape, hardening and grinding. Structurally the condition of the steel remains the same and it is very evident from the photographs shown that the internal condition of large high speed rounds is not desirable.

The method involved in forming a forged cutter blank is illustrated in Figs. 7 and 8. The bar stock, about one half the diameter of the desired cutter, which has previously received a large amount of reduction, is cut to the length required to furnish the necessary material after upsetting. The direction in which work has been applied, however, has been entirely longitudinal or in a direction parallel to the axis of the bar. This fact is sometimes responsible for failure of cutters made directly from bar stock especially in the larger sizes, an account of the tendency toward a grain structure which may be described as "woody" or fibrous and which is in a sense analogous to the longitudinal grain in a piece of wood. The tendency toward carbide stringers is shown in Figs. 13 and 14 which is a longitudinal section of a piece of high speed steel from bar stock ⅝-inch in diameter. Steel showing this effect tends toward planes of weakness along the lines of the segregation, which if present along the cutting edges of the tool may cause flaking off.

It is clear from Figs. 7 and 8 that after the cylinder of steel has been cut to length it is hammered and upset in a direction perpendicular to the direction in which work has previously been done. The forging is done at a temperature of approximately 2000 degrees Fahr. under a steam hammer; the disk is upset to a thickness about the size of the cutter. It is then reheated and finished in the recessing or forming dies. This procedure squeezes the metal adjacent to the outer circumference into forcible contact with the sides of the die and each blow compresses the metal heavily at the vital points. The excess metal forms a slight flash which is trimmed off later.

The extent of the refinement and compression is forcibly brought out in Figs. 11, 15 and 16. Fig. 11 is a photograph of the cross section of a forged high speed milling cutter blank in the hardened condition. It was highly polished and then etched with tincture of iodine to make the structure visible, and the photomicrographs, Figs. 15 and 16, show the structure at the points *A* and *B*.

Merely upsetting a bar into a disk or "pancake" between flat faced hammer dies does not produce the result referred to in compressing the metal heavily at the circumference, as it tends to open up the edges of the disk and the disk is very apt to split radially as shown in Fig. 10, making the structure porous at the most vital points in the cutter. This difficulty is not encountered in the drop forging process as the metal is forcibly driven into the recess of the dies and the tendency to split does not exist.

The forging process for the manufacture of cutters while more expensive from a manufacturing standpoint possesses advantages which

(*Continued on Page* 251)

SALT BATHS FOR HEAT TREATING

By Sam Tour

Introduction

This paper is not intended to cover an extended scientific study of heat treating salts nor was the work covered by this paper such a study. It is simply a description of the work done by the writer on the subject up to the present time. The work itself is not complete and a solution of the problem of finding a salt or salts which are satisfactory for the various heat treating operations has not been found.

General

WHEN in heat treating work it becomes necessary to heat treat finished machine pieces of steel without scaling, oxidation, carburization, or decarburization some other method than open furnace treatment must be devised. It is true that by various means, such as keeping a reducing atmosphere in the furnace, or by use of a well sealed furnace the amount of scaling can be cut down. If however the steel being treated has been cut into complicated shapes, or is of intricate design, and especially if it has had any amount of engraving done upon it, it becomes impractical to treat it in an open furnace.

If the open furnace method is not used there remains two other methods. One is to pack-harden, pack-hardening means the packing of the pieces to be hardened in some apparenlty neutral material to protect them from oxidation. The usual material used is charcoal and cast iron chips. This pack hardening functions fairly well and when used occasionally is probably the proper method to use. In other words, if a heat treating room has only an occasional use for a hardening treatment which will not have a deleterious action on the surface it is logical and practical to use the pack hardening method. Pack hardening however, is no where near perfect in its protection against scaling, carburization and decarburization of the surface. Pack hardening is a slow and inefficient method of hardening. Large pieces with both heavy and light sections are very hard to handle in a pack hardening treatment. Removal from the packing material introduces a delay in quenching with its attendant loss of heat. A certain amount of oxidation takes place in the short interval of time that the steel is exposed to the atmosphere after removal from the furnace and before immersion in the quenching medium.

The remaining method for hardening as referred to above is with the use of molten baths. Modern methods of heating steel in the various operations of hardening and tempering demand the use of a number of different types of molten baths. Baths of molten lead have long been and still are extensively used for treating tools etc., of simple design that are properly quenched from temperatures below about 1472 degrees Fahr. If the steel being treated requires a temperature much higher than 1472 degrees Fahr. or if the piece is of such intricate design as to tend to entrap the molten lead or again if we are very particular

A paper presented before the New York Chapter. The author Sam Tour, is metallurgist, Doehler Die-Casting Co., Brooklyn, N. Y.

in regard to the surface condition of the piece after treatment the molten lead bath is not satisfactory. Baths of molten salts are becoming more and more common.

Molten salt baths can be divided into the following classes:

1—Case hardening or cyaniding baths.
2—Tempering baths for temperatures from 482 to 1022 degrees Fahr.
3—Tempering and hardening baths for temperatures from 1022 to 1517
4—Hardening bath for temperatures—1202 to 1697 degrees Fahr.
5—High speed hardening baths for temperatures up to 2372 degrees Fahr.
degrees Fahr.

Cyaniding

For case hardening or cyaniding the bath usually used is composed of a mixture of sodium cyanide NaCN, sodium chloride NaCl and sodium carbonate Na_2CO_3. Some prefer to start with a ternary mixture of these whereas some start with the binary NaCN and NaCl. When heated up the NaCN at the surface of the bath gradually changes over into Na_2Co_3. Also while kept molten some of the NaCl is lost by volatilization and some by decomposition with water in the atmosphere. The net result; and one not often realized by the use is that one may be starting with a 76 per cent NaCN 24 per cent NaCl mix and may have in his molten bath only 15 per cent NaCN 10 per cent NaCl and 75 per cent Na_2CO_3. The question of cyaniding bath is one worthy of an entire paper and so will not be further discussed herein.

Tempering

For tempering baths for temperatures from 482 to 1022 degrees Fahr. mixtures of sodium nitrate $NaNO_3$ and potassium nitrate KNO_3 are often used as well as $NaNo_3$ and $NaNO_2$. According to curves given in Landolt and Boernstein, $NaNO_3$ melts at 586 degrees Fahr., KNO_3 at 642 degrees Fahr and the two at the composition of 50 molecular per cent of KNO_3 form a eutectic freezing at 424 degrees Fahr. Also, $NaNO_2$ melts at 543 degrees Fahr. and $NaNO_2$ and $NaNO_3$ at a concentration of 50 molecular per cent of $NaNO_2$ form a eutectic freezing at 430 degrees Fahr. Baths of these mixtures function fairly well for temperatures up to 797 degrees Fahr., but cause a certain amount of oxidation at temperatures above 797 degrees Fahr. In other words there is still to be found a salt to function satisfactorily bebetween 797 degrees Fahr. and 1022 degrees Fahr.

Hardening

$CaCl_2$ and NaCl

Tempering and hardening baths for temperatures between 1022 degrees Fahr. and 1517 degrees Fahr. are used for tempering high speed steel and for heating, for quenching carbon tool steels. A fairly satisfactory bath for this purpose, when one learns some of its idiosyncracies is a eutectic mixture of calcium chloride $CaCl_2$ and sodium chloride NaCl. $CaCl_2$ melts at approximately 1422 degrees Fahr. and NaCl at approximately 1472 degrees Fahr. whereas their eutectic mixture consisting of 72.5 per cent $CaCl_2$ by weight and 27.5 per cent NaCl freezes at 941 degrees Fahr. This salt mixture is sold to the trade by various concerns under special trade names. A new case hardening or really a

cyaniding process known as the "Shimer Process," uses a molten bath of this composition as a base and by the addition with the steel of lumps of cyanimide a cyaniding action is produced.

To make up a satisfactory salt bath of this composition it is not necessary to start with chemically pure or exceptionally high grade salt. Commercial fused calcium chloride and commercial table salt answer the purpose very nicely. The mixture will not function properly however when first made up. It is necessary to heat it up to around 1652 degrees Fahr. several times before it is possible to use it for steel treating purposes and have the steel come out with a clean bright surface. When first made up this mixture has a decided pitting action on steel. After heating a number of times it has been found that this pitting action gradually diminishes and that after heating and cooling about four times the action has entirely ceased. From this point on, this non pitting mixture is satisfactory in many ways for the heat treating of steel but it has its serious disadvantages. Calcium chloride, which constitutes the bulk of this salt mixture, is very hygroscopic and also is a rust promoter. The operation of the bath results in a certain amount of fuming. These fumes carry and deposit calcium chloride into every part of the building and there the calcium chloride attracts moisture and immediately rapid rusting and corrosion sets in. In addition to this disadvantage the use of a bath containing any calcium chloride requires that the steel after quenching be carefully scrubbed and washed to remove the last traces of salt before it is tempered in order that corrosion and pitting of the surface be avoided. The use of a hot sal soda solution or some one of the standard cleaning compounds for this washing has been found quite satisfactory. The sal soda changes the remaining traces of $CaCl_2$ to the carbonate form which is not a very active rust promoter. Some of the standard cleaning solutions may be somewhat better than the straight sal soda solution in that they not only have an action similar to that of sal soda but they leave a slight deposit on the steel which assists in preventing further rusting.

In was found that this $CaCl_2$ and NaCl mixture could not be made to function properly when made up in a clay or graphite pot. At first it was thought possible that the pitting action which occured was not due to the presence of the clay but due to the absence of iron which might be necessary to combine with and remove impurities present in the salt bath. If this were true, then the addition of cast iron chips should have eliminated this difficulty but on trial this was found not to be the case. Mr. H. V. Thompson, *Transactions* of the English Ceramics Society Vol. 17, 1918, in studying the dissociation of salt found that fused NaCl and the moisture of the atmosphere reacted with SiO_2, Fe_2O_3, Al_2O_3 and clays. Some reaction of this nature no doubt is the explanation of the difficulties encountered with these two salts when attempts are made to use them in clay or graphite crucibles. These salts work satisfactorily in iron, steel or alloy steel pots.

In passing, a certain peculiar characteristics of this salt mixture on cooling seems to be worth mentioning. Just after the molten salt has solidified and is at a temperature around 932 degrees Fahr. it is very dark grey, almost black in color. As this salt cools however it gradually becomes lighter in color until around 257 degrees Fahr. it

is of a light grey color and in the form of a solid rather strong columnar crystalline mass. At about 212 degrees Fahr. however the salt suddenly changes from this light grey color to white. This change is accompanied by an expansion which causes the previously solid chunks of salt to break up and crumble into small pieces. These changes are probably the external evidence of the breaking down of a double salt of calcium and sodium which forms in the molten bath but which is not stable at room temperatures. The exact nature of these changes are probably not of any importance insofar as heat treatment of steel is concerned.

$CaCl_2$-NaCl-KCl

The ternary mixture of potassium sodium and calcium chlorides has been studied by several investigators. A eutectic mixture of these salts consists of 50 per cent KCl, 30 per cent $CaCl_2$ and 20 per cent NaCl and freezes at about 986 degrees Fahr. This mixture presents a case similar to the $CaCl_2$ and NaCl mixture in regard to pitting action. It is a little easier to wash off after quenching but its loss by volatilization is considerably greater and is in such proportions as to destroy the eutectic nature of the entire mix. Insofar as $CaCl_2$ content is concerned it presents the same disadvantages, although not so accentuated as does the straight $CaCl_2$ and NaCl mixture. With respect to disagreeable fumes and pot life it is inferior to the $CaCl_2$ and NaCl mixture.

Another eutectic mixture of these three salts as found by C. A. H. Lantsberry, Journal of the Society of Chemical Industry Vol. 39 1920. is composed of 70 per cent $CaCl_2$, 25 per cent NaCl and 5 per cent KCl which freezes at approximately 932 degrees Fahr. Thus no real advantage is gained by the addition of the more expensive KCl to a mixture of $CaCl_2$ and NaCl.

Considerable work has been done on this ternary system by various investigators. The most notable papers appearing in the literature are those by Menge and by Lamplough. (Menge, Z. *Anorg. Chem.,* 1911, 9,162.) (Lamplough, *Proc.* Camb Phil. Soc., 1911, 103-196.)

$BaCl_2$ and NaCl

A binary mixture of barium chloride $BaCl_2$ and sodium chloride NaCl has been much used as a salt for heat treating purposes. This mixture being free from $CaCl_2$ is free from the disadvantages of being hygroscopic, and of being a strong rust promoter. According to various authorities $BaCl_2$ melts at from 1580 to 1760 degrees Fahr. According to Le Chatelier a eutectic mixture consisting of 22.25 per cent by weight of NaCl and the balance $BaCl_2$ freezes at 1175 degrees Fahr. The disadvantages of this salt are its rather high melting point, the difficulty in cleaning the surface of the steel after quenching in oil, and the tendency of the salt film on the steel to act as an insulator and cause a localized decrease in effect of quenching and to cause soft spots. This salt also has a tendency to pit the surface of the steel after the bath has been run for a few days. On one or two occasions it was found that the addition of a small amount of NaOH retarded this action.

$BaCl_2$ and $CaCl_2$

A mixture of $BaCl_2$ and $CaCl_2$, according to Ruff and Plato in Landolt & Boernstein containing 35 molecular per cent of $BaCl_2$ (approxi-

mately 45 per cent $BaCl_2$ by weight) freezes at 1112 degrees Fahr. In our tests we found this mixture to freeze at 1030 degrees Fahr. The only explanation we can find for this is that some of the previous mixtures tried (a $NaCl$-Na_2CO_3 mixture) might have remained in the pot and have thus lowered the freezing point.

At about 1148 degrees Fahr. this salt takes on a blackish color which becomes more intense as it nears the freezing point. The frozen salt has a dark slate color. Due to the large amount of $CaCl_2$ in this mixture it is very hygroscopic and picks up a large amount of water over night.

As regards lack of pitting action and its cleaning off properties this salt leaves little to be desired. On the very first melting a piece of alloy steel cleaned off perfectly and showed no pitting. In this respect this mixture is as good as any we have found but the large amount of $CaCl_2$ in it prohibits its use. This is unfortunate as it is acceptable in other respects, especially on account of its very low freezing point.

$BaCl_2$-KCl-NaCl

A ternary mixture of $BaCl_2$, KCl and NaCl, has been studied also. E. Vortich—The system $BaCl_2$ KCl and NaCl, Neuen Jahrbuch F. Min. etc. Beil. Bd. 38 p 513., found a eutectic mixture of these salts freezing at 1010 degrees Fahr., with the composition 28 molecular per cent $BaCl_2$, 39 molecular per cent KCl and 33 molecular per cent of NaCl. H. Gemsky, Neuen Jahrbuch F. Min. etc. Beil. Bd. 36 p. 513 found a eutectic freezing at practically the same temperature but gives the composition as 24 molecular per cent $BaCl_2$, 39.5 molecular per cent of KCl and 36.5 molecular per cent of NaCl. This same system has also been studied and discussed by Ernst Janecke, Hanover, *Centralblatt Min. Geol.* 1919 pages 271-4. This system has also been reviewed theoretically by Liebisch, Zeit. Anorg and Allgem. Chemie. 99, 50-66, (1917). None of the work referred to above was along the line of a practical application of this mixture as a salt bath for heat treating purposes. The writer made up a mixture of salts approximating the composition given above and consisting of 50 per cent $BaCl_2$ by weight, 30 per cent $CaCl_2$ and 20 per cent NaCl, and found that this salt mixture pitted when first made up and was cleaned off only with great difficulty after only the first trial. After heating it up the third time it has ceased to pit and cleaned off more easily but still not easy enough. Even after reheating five times it failed to develop good cleaning properties. It was also found that the salt fumed quite profusely when at temperatures around 1652 degrees Fahr. The addition of ½ per cent of NaOH to the mixture did not seem to have any effect on its cleaning, pitting or fuming properties. The excessive fuming and the difficulty in cleaning makes this an unsatisfactory heat treating salt.

NaCl and KCl

The binary system NaCl and KCl forms a eutectic at a composition of 50 molecular per cent of KCl, which freezes at 664 degrees Cent. 1227 degrees Fahr). This excessively high minimum temperature and the excessive fuming of the molten bath at temperatures around 850

degrees Cent. (1562 degrees Fahr.) makes this mixture an unsatisfactory one for use in the heat treating room.

Na_2SO_4 and NaCl

The binary system sodium sulphate Na_2SO_4-NaCl forms a eutectic, a composition of 46 molecular per cent of Na_2SO_4 which freezes at 1155 degrees Fahr. Two attempts were made to try this mixture but on each occasion the salt fused its way through the one inch thick cast iron pot being used, before the total salt mixture was entirely molten. In other words, this salt mixture reacts with iron so readily that it is out of the question as a heat treating salt bath material.

Na_2CO_3 and NaCl

According to Le Chatelier, Landolt and Boernstein Physical Tables, the binary system sodium carbonate Na_2Co_3 and NaCl forms a eutectic at a composition of 34.7 per cent by weight of NaCl with a freezing point of 1148 degrees Fahr. However, a hard solid crust forms on the surface at 1202 degrees Fahr. so that the salt cannot be used below that temperature. This mixture does not pit but forms a coating of black, carbonaceous material resembling lamp-black, which cannot be removed from the surface even with emery. Repeating heating does not improve the salt.

Conclusion

A number of different combinations of salts are used and recommended by various people, but each has some vital defect or objectionable quality. Most of these combinations are eutectic mixtures of metallic chlorides, such as calcium chloride, barium chloride, sodium chloride and potassium chloride.

Calcium Chloride is hygroscopic, must be carefully washed off the steel, or will cause corrosion, and has a tendency to pit. Calcium chloride alone has a melting point around 1420 degrees Fahr. which is too high for use.

Barium Chloride alone has a melting point variously stated from 1580 to 1760 degrees Fahr. which is too high for use except for high speed steel. It is claimed that barium chloride develops a pitting action after it has been in use a few days at temperatures around 2012 degrees Fahr. and almost immediately at temperatures around 2372 degrees Fahr. Some authorities say, but this has not been found true by the writer, that the addition of a small amount of NaOH every few days keeps down this pitting action.

Sodium Chloride melts around 1472 degrees Fahr. and appears to be rather inert as far as corrosive and pitting action is concerned, except at the surface in contact with air. The original impurities however in sodium chloride such as magnesium salts, sulphates, etc., might be the source of the trouble which has occasionally been found with fused sodium chloride. The melting point of sodium chloride is too high however for it to be used alone.

Potassium Chloride melts at around 1438 degrees Fahr. and has the same objectionable features as sodium chloride, and in addition it

has greater volatilization. Fumes of any of these salts are of course objectionable although those of calcium chloride are the most objectionable.

Sodium Carbonate melts at around 1508 degrees Fahr. and thus has too high a melting point to be used alone. There is some question as to its decarburizing effect when used at high temperatures on high carbon steel especially.

Potassium Carbonate melts at around 1652 degrees Fahr. and is open to the same objections as sodium carbonate.

Some eutectic mixture of two or more of the above salts will no doubt be the best solution of the problem.

A proper salt bath for the heat treating of complicated parts of high grade steel other than high speed steel should meet the following requirements:—

1. *It should have no corrosive or pitting action upon the steel.*
2. *It should have neither a carburizing nor de-carburizing action on the steel.*
3. *It should melt at some temperature below* 1020 *degrees Fahr.*
4. *It should not give off objectionable fumes at* 1700 *degrees Fahr.*
5. *It should not attack the cast iron or alloy pot used for heating.*
6. *It should not deposit a sludge in the bottom of the pot.*
7. *It should leave only a thin film of molten salt adhering to the piece of steel as the piece is lowered into the quenching bath.*
8. *The salt and oil mixtures on the steel after quenching should be easily removable, by rubbing with waste.*
9. *The salts should be such that no harm would be done if the steel is tempered while some of the salts still remain upon it.*
10. *The salts should be non-hygroscopic.*
11. *The salts should have no rust promoting action.*

The reason for most of the above requirements are quite obvious. The ideal salt bath would be one which gave no pitting action, which gave the maximum life of pot, and which would not require careful washing of the piece of steel after quenching. Such an ideal salt has as yet not been found so far as the writer is aware.

Advantages of the Forged Milling Cutter

(*Continued from Page* 244)

cannot be overlooked by the user of milling cutters and the fact alone that the largest users are now beginning to specify forged cutters is sufficient evidence that the claims of increased performance made for the forged cutter are being realized.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

NEW QUESTIONS

QUESTION 51. *What are the causes of black fractures in high carbon tool steel?*

QUESTION 52. *Is the Brinell hardness number of a given piece of steel, an accurate measure of its machinability?*

QUESTION 53. *What is the composition of the so-called semi-steel?*

QUESTION 54. *Is it possible for a piece of commercially pure iron in contact with a piece of high carbon steel, to absorb carbon from the steel?*

QUESTION 55. *What are the causes of soft spots in the carburizing of steel?*

ANSWERS TO OLD QUESTIONS

QUESTION NO. 27. What is the function of the high phosphorus and the high sulphur content in the so called automatic screw stock steel?

QUESTION NO. 30 *How do the physical properties of a chrome molybdenum steel vary from the physical properties of a chrome vanadium steel after suitable heat treatments have been given to each?*

ANSWER. By J. S. Vanick, metallurgist, U. S. Bureau of Standards, Washington, D. C.

An immediate difficulty in answer to this question, lies in defining, what is ment, in terms of composition, by a chrome-molybdenum steel. The chrome-vanadium steels are not hampered by this difficulty.

A comparison of the mechanical properties, viz., strength, ductility and hardness of the usual chrome-vanadium steel of the .30 C type, may be made from the data presented by Hoyt (1) French, (2) and Sargent (3), (4). These data show, for oil-quenched steels, an advantage in strength in favor of the chrome-vanadium steel.

Water quenching the chrome-molybdenum steel, brings up the strength, which, however, remains below the oil-hardened, chrome-vanadium maximum, indicating that the strength possibilities of chrome-vanadium steels are superior to those of chrome-molybdenum steels. High ductility values, reported by Sargent, are not confirmed by French. The high ductility of chrome-

molybdenum steels approaches the lower values for chrome-vanadium steels when the corresponding tensile values are more nearly equal.

Hardness values for the two steels are quite similar when equivalent values for strength and ductility prevail.

Data Sheet

Steel Compositions

	I	II	III	IV	V
C	.32	.32	.27	.39*	.30
Mn	.55	.55	1.01*	.76	.60
Cr	.90	.90	.88	1.07	1.0
Mo	.37	.37	.52	....	....
V	...	...	....	.21	.18

* High content

Heat Treatment
I Quenched in oil from 1700° F. Tempered as shown
II " in water from 1600° F. " " "
III " in oil from 1550° F. " " "
IV " in oil from 1600° F. " " "
V " in oil from 1650° F. " " "

Tensile Strength

Tempered ° F	I	II	III	IV	V
none	.....	.....	181,000	.....	214,000
200	.....	.....	.....	.....	.....
400	143,000*	230,000	187,000	250,000	245,000
600	143,000*	220,000	.....	230,000	236,000
800	143,000	210,000	176,000	200,000	211,000
1000	135,000	190,000	.....	170,000	163,000
1200	122,000	150,000	125,000	130,000	149,000

Elastic Limit (method, not indicated)

400	135,000*	205,000*	.....	..215,000	230,000
600	135,000*	205,000*	.....	205,000	227,000
800	130,000	195,000	.....	185,000	180,000
1000	125,000	175,000	.....	150,000	142,000
1200	110,000	140,000	.....	110,000	130,000

Elongation in 2 in.

none			4.0		1.0
400	15.0*	11.0	6.8	8.0	6.0
600	15.0*	11.0	....	10.0	8.0
800	16.0	12.0	10.0	13.0	11.0
1000	17.0	15.0	....	17.0	16.0
1200	21.0	20.0	20.8	21.0	18.0

Reduction of Area

none			5.9		6
400	56*	46	10.2	17	20
600	57*	48	....	22	43
800	58	51	36.6	33	48
1000	60	56	....	44.0	53
1200	64	63	63.0	54	60

Approximate

Differences in the compositions of the chrome-molybdenum steels above, particularly in C, Mn and Mo, prevent better comparisons with equivalent vanadium steels. More comprehensive studies of molybdenum steels are necessary to better determine the effect of the element.

(1) Hoyt, S. L. Metallography, Part II, The Metals and Common Alloys, Table 122, p. 429.

(2) French, H. J. Trans. A. S. S. T. June, 1922, p. 788, Table XII.

(3) Sargent, G. W. Trans. A. S. T. M 1920, vol. 20, Fig. 2, p. 12.

(4) Climax Molybdenum Co., Catalog, Molybdenum Commercial Steels, p. 35.

QUESTION NO. 35. *What is the difference between red annealed and blue annealed sheet steel?*

QUESTION NO. 38. *What regulations are recommended to reduce the fire hazzard of quenching tanks?*

QUESTION 41. *Is the X-ray examination of steels commercially practicable?*

ANSWER. A considerable amount of research and laboratory work has been done on the X-ray examination of metals and there are many factors which effect this method of examination of metals. Many rearrangements and re-design of equipment have been necessary in order that the operator could get satisfactory results. It is assumed that the author of this question refers to the examination of metals by means of X-ray, to determine whether or not there are any blow holes, or pipes within the metal. In Volume 1 of the Journal of the American Steel Treaters' Society, Sir Robert Hadfield discusses the subject of radiometallography in which he reproduces X-ray photographs of metal castings showing blow holes and inclusions in the castings. The article states that the present application of X-ray photography makes it possible to use only comparatively thin specimens of metal, while the usual type of castings which are desired for inspection are of considerable size. So far, the information which is available on the subject of X-ray examinations of metals indicates that this method of examination is not commercially practicable, however, it is entirely feasible that such a method will be developed as a commercial method of inspection.

QUESTION 44. *Is it advantageous for the purchaser to conduct a test on various brands of high speed steel before deciding upon placing his contract?*

ANSWER. The only true test for a brand of high-speed steel is the service that it gives by continued performance month in and month out under actual shop conditions. The average buyer of high-speed steel is not justified in conducting a test, but can well continue to purchase his requirements of high-speed steel from a reputable manufacturer of a brand that is nationally known. The manufacturer of high-speed steel is always willing to co-operate with the trade in the conducting of a test and is much interested in the information received from a well conducted test. A test of high-speed steel, to be valuable, should be conducted in a manner as nearly approaching actual working conditions in the plant in which the test is made, as is practical. In conducting a test a few reputable brands of high-speed steel should be allowed to enter. The test should be conducted along lines laid down by customer and all competitors should be treated equally. All tools entered should be of exactly the same size and shape. There is much difference of opinion as to the best practical method of conducting a test, and the decision as to how the test should be conducted should be left to the customer, who should co-operate with the manufacturers in devising a test which would give the best basis for conclusions as to how the particular brands of high speed-steel would perform under actual shop conditions.

QUESTION 46. *Is the practice of buying high-speed steel by brand names instead of physical, chemical and metallurgical specifications justifiable?*

ANSWER. The practice of buying high speed steel by brand names is justifiable. The guarantee behind high speed steel is the standing and reputation of the manufacturer, who should maintain in his employ metallurgists and experienced service men who will defend the quality of his product and be ready at any time to heat-treat and demonstrate to buyer's satisfaction that the product furnished by him will meet any of his reasonable requirements. The customer's specifying the chemical, physical or metallurgical properties relieves the manufacturer of his responsibility as to quality. Quality is not dependent upon the chemical composition and poor high speed steel can be made within any limits of chemical contents that could be commercially met by a manufacturer of best quality high speed steel. In purchasing high speed steel by brand name the buyer places responsibility for performance clearly with the manufacturer. The specifying of physical, chemical or metallurgical limits by buyer would lead to endless controversy and would positively retard, in fact, completely arrest the progress of the industry.

The manufacturers of high speed steel should co-operate with the user to the extent of submitting upon request rejection limits as to chemical content of those elements which vitally affect the steel treater's work. It is not desirable that the manufacturer's rejection limits be published broadcast. The buyer has the right to demand that high speed steel purchased by him should be within the generally accepted analysis of high speed steel. Chemical composition is a basic consideration, but the quality is dependent upon many other factors, the most important of which is the human element. No steel treater can question the fact that the results obtained from heat-treating depend upon the operator. The operator will use all modern appliances, such as pyrometer, automatic temperature control, quenching machines, etc., but the results obtained depend upon his individual experience and skill. The manufacture of tool steel is and will continue to be a handicraft industry.

Modern tool steel practice has changed from that of the past, not by the use of labor-saving machinery, but by the use of scientific devices which aid and guide the skilled craftsman in producing a steel of higher quality and greater uniformity. It is upon the intelligence, experience and skill of the individual that quality of tool steel depends.

QUESTION 47. *What is meant by "secondary hardness" in the tempering of high-speed steel.*

ANSWER. The term "secondary hardness" has been applied to the increase in hardness of a piece of high-speed steel, over the original hardness resulting from quenching the specimen from a high temperature, when it is tempered at a temperature in the neighborhood of 600 degrees Cent.

QUESTION 48. *What are dendrites and how may they be detected?*

QUESTION 49. *Can dendrites be removed through a proper heat treatment?*

(*Continued on Page* 271)

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

TREATING HIGH SPEED TOOL STEEL. By H. K. Ogilvie in *Iron Trade Review,* October 26, 1922. Reprinted from a paper presented at the meeting of the Iron and Steel Institute at York, England, Sept. 5-6.

This paper discusses the process of manufacture of high speed steel, including the crucible method and the basic lined electric furnace method which is usually used for making tungsten steel for lathe turning tools, cutters and drills.

The various types of ingot molds and the method of pouring, temperatures, etc., are discussed. Fractures and microscopic structures resulting from varied heat treatments, together with hardness tests, are discussed.

OVERSTRAIN, INTERNAL STRESSES AND CREEP. By Zay Jerries and R. S. Archer, in *Chemical and Metallurgical Engineering,* Vol. 27, No. 17, Oct. 25, 1922.

The authors liken the effects of working hot-rolled iron or mild steel at blue heat to similar conditions observed in nickel and certain alloys. These phenomena and the results of overstrain are all due to rapid acquisition of increased strength on slip planes.

SHRINKAGE AND EXPANSION OF HIGH-SPEED STEEL DUE TO HEAT-TREATMENT. By M. A. Grossmann, in *Chemical and Metallurgical Engineering.* Vol. 27, No. 11. September, 1922.

The author describes tests which were recently undertaken to obtain data on the amount which should be allowed in high-speed tools for shrinkage or expansion resulting from heat treatment. Volume and hardness changes, thermal analysis and microscopic structure indicate that secondary hardness in high-speed steel is due to the decomposition of stable austenite into martensite which is different from martensite formed during quenching.

MECHANICAL PROPERTIES AS AFFECTED BY GRAIN SIZE. By Zay Jeffries and R. S. Archer. In *Chemical and Metallurgical Engineering.* Vol. 27, No. 16. October, 1922.

This paper discusses the reasons that variation in the average size of crystalline grains comprising the metal may be expected to influence the mechanical properites of the aggregate. Grain boundaries add a certain stiffness to a metallic aggregate. Fine grain size generally involves higher tensile strength and hardness with greater reduction of area. Maximum elongation requires medium grain size.

INVAR, ELINVAR AND OTHER NICKEL STEELS. By W. D. Williams. In *Raw Material.* Vol. V, No. 9. October, 1922.

The author discusses quite fully the history of nickel steels, especially of the invar type, including electrical properties, thermal critical points and mechanical properties. This is the first of a series of articles dealing with nickel steels.

MECHANICAL PROPERTIES OF COMMERCIAL IRON. By Zay Jeffries and R. S. Archer. In *Chemical and Metallurgical Engineering.* Vol. 27, No. 14. October, 1922.

This paper discusses the definitions of various terms used in the art of testing materials, and a discussion of how various circumstances surrounding the test affect the results on annealed bars of common structural metals.

ADSORPTION A CRITERION OF CORROSION. By D. D. Saklatwalla. In *Chemical and Metallurgical Engineering.* Vol. 27, No. 13. September, 1922.

Various theories on subject briefly discussed.

GRAPHITIZATION IN A CARBON TOOL STEEL. By H. S. Rawdon and S. Epstein. In *Chemical and Metallurgical Engineering.* Vol. 27, No. 13. September, 1922.

The work covered in this article is in connection with a paper on the same subject by A. W. F. Green. The authors worked upon a specimen submitted by Mr. Green and found no expalanation of the peculiar behavior of the material.

EFFECT OF TEMPERATURE, PRESSURE AND STRUCTURE ON MECHANICAL PROPERTIES OF METAL. By Zay Jeffries and R. S. Archer. In *Chemical and Metallurgical Engineering.* Vol. 27, No. 15. October, 1922.

This paper deals with effect of temperature on the crystal structure of a metal which in turn affects the mechanical properties of the aggregate. It is found that recrystallization, annealing, cold work and foreign inclusions have a profound effect on the size and the shape of crystalline grains and therefore on the mechanical properties. The discussion includes a study of the mechanical properties of a single crystal.

RECENT DEVELOPMENTS IN FATIGUE OF METALS. By H. F. Moore and T. M. Jasper. In *Iron Age.* Vol. 110, No. 13. September, 1922.

The authors describe the latest type of fatigue testing machine used in their laboratory at the University of Illinois. The effects of heat treatment are discussed as affecting the fatigue resisting properties of metals. Several charts are presented showing the various mechanical properties of the steels tested compared to fatigue strength.

ALLOY CASTINGS FROM ELECTRIC FURNACES. By L. J. Barton. In *Iron Age.* Vol. 110, No. 13. September, 1922.

Among some of the newer lines of metallurgical endeavor is the manufacture of alloy steel castings to be heat-treated and used as a substitute for forgings and for purposes where ordinary grades of steel castings will not stand up under the duty imposed. The author discusses nickel, chromium and chrome-nickel steel made on the Pacific coast, including their production properties and heat treatment.

PEARLITIC AND SORBITIC MANGANESE STEELS. By J. H. Hall. In *Iron Age.* Vol. 110, No. 13. September, 1922.

This article makes a plea for castings containing about one per cent manganese instead of the lower contents. The author reviews some of the literature on the subject and discusses the heat treatment of steels containing varying contents of manganese.

INFLUENCE OF MASS IN HEAT TREATMENT. By E. J. Janitzky. In *Iron Age.* Vol. 110, No. 13. September, 1922.

This paper discusses the role of special elements such as nickel, chromium and molybdenum in counteracting the effect of size. Experimental data is given on sections 0.5 to 3 inches in diameter.

TREND OF SPECIFICATIONS FOR STEEL CASTINGS. By E. R. Young. In *Blast Furnace and Steel Plant.* September, 1922. Page 463.

This article involves a general discussion covering the important features of steel castings specifications such as chemical composition, physical properties and some of the newer methods of testing.

ACID-RESISTING METALS AND ALLOYS. By G. A. Drysdale. *Mechanical Engineering.* Vol. 44, No. 9. September, 1922. Page 579.

An account of research work carried out on various non-ferrous metals and alloys, with especial reference to their use in the manufacture of mine pumps and chemical apparatus.

Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Criticism in This Column—Members Submitting Discussions Are Requested to Give Their Names and Addresses

A COMMUNICATION recently received from Mr. Arthur G. Henry, of the Vanadium Alloys Steel Co. contained the following historical sketch of the Bessemer Process. Mr. Henry spent some of his early years at the Ebbw Vale Iron Works:

The Bessemer Process—Historical

The story of the early struggles, defeats, and successes in developing the Bessemer Process of making steel has all the fascination of a romance. Sir Henry Bessmer, in an autograph letter which was presented to the American Institute of Mining Engineers by the then Sir James Kitson, Bart., has given a graphic account of what led to the experiments which ultimately brought him so much well-earned renown. While engaged with projectile trials in the fortress at Vincennes, an officer made a casual remark about superior material for guns, which arrested Bessemer's attention. "This casual observation," says Sir Henry, "was the spark that kindled one of the greatest industrial revolutions that the present century has to record, for, during my solitary ride in a cab that night from Vincennes to Paris, I made up my mind to try what I could do to improve the quality of iron used in the manufacture of guns."

It was at the Cheltenham meeting of the British Association on August 11, 1856, that Sir Henry Bessemer made known to the world his process. Licenses were in great demand. The idea of converting iron into steel in a few minutes without the aid of external fuel was startling, and aroused the curiosity of manufacturers of wrought iron. But the imperfect knowledge of the chemical reactions in the process and the influence of the volume and pressure of air, as well as a wrong conception that any class of pig iron could be used in the process, contributed to a rapid reversal of opinion regarding the merits of the discovery.

Other investigations in this country and abroad had been working toward the same object. The interest aroused by the patent of Joseph Gillott Martien, of Newark, New Jersey, U. S. A., dated Sept. 15, 1855, and the experiment of Mr. George Parry, of the Ebbw Vale Iron works, in October or November, 1855, have long since been forgotten. Dr. Percy, in referring to Mr. Parry's experiment, says that "if an accident had not unfortunately occurred, Bessemer might have been shorn of his glory."

On January 10, 1857, William Kelly obtained his first American patent, and claimed, says, Mr. R. W. Hunt, "priority in the discovery of the principles of the process, and the Patent Office allowed his claim by granting his patents." Bessemer had, however, obtained patents for his process in America dated February 12, 1856, and August 25 of the same year, and while the Kelly Pneumatic Process Co., which was formed in 1863, and finally abandoned in 1869, was allowed to operate the patents of Kelly, and was

the first to make Bessemer steel in America at the works at Wyandotte, in the fall of 1864, under the direction of Mr. W. F. Durfee, it has long since been admitted that the inner and governing principle of the great discovery emanated from the brain of the genius Henry Bessemer.

The pioneer of the Bessemer process in America, and one to whom all steel men would readily award the honor of having very largely contributed to its development and success, was Mr. Alexander M. Holley. It was he who negotiated with Bessemer the American patent rights for the Winslow, Griswold, and Holley Co., and started, in February, 1865, the first 2½-ton converter at Troy, New York, thus inaugurating the Bessemer steel production of America, which, during the year 1911, amounted to 7,947,849 tons. Mr. Robert W. Hunt, in his presidential address in 1906 to the American Institution of Mining Engineers, said, in referring to American Bessemer practice, "that the names of Holley, John Fritz, George Fritz, William R. Jones, Daniel L. Jones, and Robert Forsyth furnish a galaxy of talent which makes plain why America so soon forged to the front in Bessemer steel production."

Going backwards to the introduction of the process in this country, perhaps the most eventful years in the early history of the process were the first two, during which Bessemer had cause to reflect that he had too readily granted licenses for a process the full significance of which was not at first realized by himself. While he was struggling to perfect his process, others were experimenting with the same object. James Riley tells of a crude experiment made in 1857 at the Coats Iron Works, Scotland, by Mr. Thomas Jackson, and afterwards of experiments at the works of William Dixon, Ltd., all of which were unsatisfactory. To Robert Mushet, in this country, and to F. Goransson, in Sweden, the Commercial success of the process is largely due. Professor Akermann, referring to Goransson's early experiments with the Bessemer process at the Edske blast furnace works in 1857, says that, "until the middle of 1858, he, like Sir Henry himself, had succeeded only exceptionally in turning out a good product while following the advice of the inventor to lay the greatest weight on having a high pressure of blast By departing from that advice, by means of larger tuyere area and an abundant supply of blast, Goransson was able, beginning with July 18th, 1858, so to shorten the time necessary for the process, and thereby increase the heat of the blow, that an improved product was obtained; and from that day forth the success of the Bessemer process was first assured." Professor Akermann also tells how Goransson sent 15 tons of ingot to Sheffield, made by his improved method, while Bessemer was still struggling to make good steel.

It would appear that the improvement made by Goransson impressed Bessemer, who for two years after the Edske trials, used Swedish pig iron only in his converter at Sheffield.

News of the Chapters

SCHEDULED REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Boston—Second Tuesday
Bridgeport—Thursday between 20th and end of month
Chicago—Second Thursday
Cincinnati—Second Thursday
Cleveland—Fourth Friday, Cleveland Engineering Society Rooms, Hotel Winton; meeting at 8:00 p. m.
Detroit—Second and fourth Monday. For meeting place call W. G. Calkins, Sec'y. Detroit Twist Drill Co.
Hartford—Friday nearest 10th of month
Indianapolis—Second Monday
Lehigh Valley—No regular night
New York—Third Wednesday
Philadelphia—Last Friday
Pittsburgh—First Tuesday
Providence—No regular night. Nov. 10th, Dec. 12th.
Schenectady—Third Tuesday
Springfield—Third Friday
South Bend—Second Wednesday
Syracuse—No regular night
Tri City—Thursday
Washington—Third Friday

STANDING OF THE CHAPTERS

There were but 45 new members received during the month. Of this number Detroit received 20, Milwaukee 6, Pittsburgh and Philadelphia 4 each, while the others were scattering.

The standing is as follows. Those printed in CAPS have advanced their positions. Those underlined have lowered their positions.

1. Chicago
2. Detroit
3. Pittsburgh
4. Philadelphia
5. Cleveland
6. New York
7. Hartford
8. Milwaukee
9. Boston
10. Lehigh Valley
11. Indianapolis
12. ROCKKFORD
13. *Syracuse*
14. Worcester
15. Cincinnati
16. Washington
17. North West
18. Springfield
19. *Tri City
20. *Providence
21. New Haven
22. Buffalo
23. Schenectady
24. St. Louis
25. Toronto
26. South Bend
27. Rochester
28. Bridgeport

*=Tied

The following comments are self-explanatory.

TO CHICAGO (1), and DETROIT (2).

According to the standing on October 1st Detroit was 27 members behind Chicago, however this number has been more than made up at the present time due to the large number of members secured by Detroit at the Convention, as well as the large number of new applications turned in. While the re-report on Nov. 1st will see position Number 1 taken by Detroit.

TO CLEVELAND (5) and NEW YORK (6).

The tie existing between Cleveland and New York has been broken, Cleveland having the advantage of one member.

TO MILWAUKEE (8) and HARTFORD (7).

Milwauke is deserving of special commendation because of the rapid and successful climb it has had during the past few months. All appreciate its efforts to pass Hartford in No. 7 and there is at the present time but one membership separating Milwaukee from the coveted 7th position.

TO SYRACUSE (13), ROCKFORD (12).

The tie between these two chapters last month has been broken in favor of Rockford which has one member more than Syracuse and consequently is in 12th position while Syracuse assumes place No. 11.

TO TRI CITY (19) and PROVIDENCE (20).

The tie existing between these two cities continued during the past month, neither chapter having shown a gain or less.

The relative position of the other chapters is practically the same as on the last report.

MEMBERSHIP CONTEST

At the delegates' meeting in Detroit a resolution was proposed and favorably acted upon that the Board of Directors of the A. S. S. T. should be requested to inaugurate a membership contest among the various chapters and offer suitable prizes to the chapters showing the largest increase in membership during a certain period.

The Board of Directors took the matter under consideration and appointed a committee to investigate the matter and make a report at the regular meeting in Cleveland on Oct. 27, 1922. This report was made to and approved by the Board and we are communicating this report to you as well as the rules governing the contest.

You will observe that the contest provides prizes not only for the increase of chapter membership but also chapter attendance at meetings. The reason for the inclusion of this feature is given in the report of the committee.

The report of the committee and rules for the contests, which begin on the dates mentioned, are as follows:

Report of the Special Committee on Cash Prize for Percentage Increase of Chapter Membership and Chapter Attendance

The special committee appointed at the meeting of the Board of Directors on October 6, 1922, to investigate the request of the Chapter delegates that a cash prize be awarded for percentage of net increase in membership in the local chapters, as well as the question of increase in attendance at local chapter meetings, beg leave to submit the following report:

The Committee has considered the action of the delegates at their session

held in connection with the recent Convention on October 3, 1922. It has also been moved by the thoughts expressed by many members of the Society that mere increase in membership should not be the sole aim of our organization. It believes rather that the continued interest of a stable membership with a sound and healthy growth will best promote the aims of the Society.

It has, therefore, recommended that combination prizes be given to the local chapters for percentage of net increases in membership and percentage attendance of members at the meetings of the local chapters. It is the committee's idea that one is quite as important as the other, and for that reason they each should count 50 per cent toward the prizes..

At the delegates' session the sum of $300.00 was recommended as the amount to be devoted, but the delegates did not have in mind the question of attendance. Your committee has thought that, inasmuch as more energy would be required to conduct the combination campaign than would be necessary if only the question of increase in membership were involved, the prizes should be larger. Furthermore, the local chapters will want to expend more funds in notices of meetings and in securing accurate records of attendance and larger prizes will make them more willing to appropriate those funds. For the above reason, your committee recommends total prizes of $500.00 which includes a fourth prize. In an organization of twenty-eight chapters, if all compete, four prizes is none too many.

The other matters contained in the resolution which is submitted herewith, are self-explanatory.

The following resolution is proposed:—

RESOLVED: That the American Society for Steel Treating, through its Board of Directors, hereby offers four prizes to be competed for by the local Chapters of the Society, and to be paid on the 15th of July, 1923 to the Chapters entitled thereto as follows:—

(a) First Prize of $200.00
(b) Second Prize of $150.00
(c) Third Prize of $100.00
(d) Fourth Prize of $50.00

The terms and conditions of the competition are:

1. The prizes shall be known as the Membership and Attendance Prizes for the years 1922-3.

2. The prizes shall be paid in cash to the four chapters showing the combination of the greatest percentage of net increase in membership from the period September 1, 1922 to June 30, 1923, and the best average attendance of members in good standing at the regular meeting of local chapters for the period beginning Dec. 1, 1922, and ending June 30, 1923. The combination standing of the several chapters in this contest will be determined on the basis of 50 per cent for percentage of net increase in membership between Sept. 1, 1922 and June 30, 1923, and 50 per cent for average attendance of members in good standing at the local chapter they shall check the matter up immediately and he shall adjust if possible meetings between Dec. 1, 1922 and June 30, 1923.

3. The basis to be used in determining the precentage of net increase in membership shall be the National Secretary's records of the membership in good standing of each local chapter on September 1, 1922 and June 30, 1923 respectively. The basis of average attendance shall likewise be the Na-

tional Secretary's records of membership in good standing of the several, local chapters on the first day of each month beginning December 1, 1922, and ending June 30, 1923. The percentage of attendance at any regular meeting of the local chapters shall be the ratio which the number of members in good standing, as shown by the National Secretary's record, bears to the number of members in good standing according to the same records on the first of the current month.

For the purpose of this contest a member is considered in good standing until the local secretary is notified by the National Office that the sending of TRANSACTIONS has been stopped for nonpayment of dues.

Nor shall a person be deemed a member until he shall have presented his application to the local chapter and paid at least 6 months' dues.

4. The National Secretary shall, on or before November 15, 1922, send notices to all chapters giving them the particulars of this contest. He shall also before December 1, 1922, adjust with the several chapters the number of members in good standing of the several chapters as on September 1, 1922 and December 1, 1922. Each month after December 1, 1922, he shall within five days after the first of the month notify the chapters of the number of members in good standing of each chapter on the first day of each month.

5. If the local chapters dispute in any way the Secretary's records they shall check the matter up immediately and he shall adjust if possible the difficulties, and refer any matter which he cannot adjust to the Board of Directors for final decision.

6. Members not in good standing shall not count in competition. When any member is not in good standing according to the *Constitution and By-Laws* of the Society, he shall be deemed to be no longer a member of the local chapter and the local chapter will be deemed to have lost such member. On restoration of good standing he shall count as a new member.

7. Within five days after each regular meeting of a local chapter, such chapter shall send to the National Secretary a statement verified by the chairman and secretary of the local chapter showing the membership of such local chapter in good standing on the first of the current month and the number of such members in attendance at the meeting. The National Secretary shall check such certificate, comparing same carefully with his records and those of the local chapter, and adjust any discrepancies that may occur between his records and the records and certificate of the local chapter. Any matters he may not be able to adjust he shall refer to the Board of Directors for final decision.

New sustaining members shall count as 2½ in the competition for the increase in membership and in the attendance competition shall be counted as one (1).

Failure for ten days after request by the National Secretary to transmit the certificate above mentioned shall disqualify such chapter from further competition in this contest.

A chapter to be eligible in this contest, must hold at least six monthly meetings in the period from December 1, 1922 to June 30, 1923.

8. In order accurately to prepare the certificate last mentioned, the local chapters will be required to circulate, at each meeting, attendance slips which shall show the name and address of the person in attendance and whether or not he is a member of the local chapter. Such attendance slips

shall be signed by those in attendance and be collected by the Secretary, or his assistants, and after verification by him shall be forwarded to the National Secretary with the certificate above mentioned.

9. All matters of detail and all rules of competition not inconsistent with the above shall be arranged for and made by the Board of Directors of the National Society.

10. The Board of Directors shall finally award the several prizes to the chapters entitled thereto. The Board shall also finally decide all matters of dispute that may arise in connection with this contest.

BOSTON CHAPTER

The Boston Chapter of the American Society for Steel Treating held its first meeting on October 17th at 7:30 p. m. at the plant of the New England Metallurgical Corporation, Andrews Square, South Boston. The speaker, Mr. J. W. Black, foreman of the hardening room of the Geometric Tool Company, New Haven, Connecticut, talked on the subject of "Hardening Twenty-Five Years ago and Today". Mr. Black's presentation was indeed interesting and was very instructive. Following the paper of the evening, all of the members were conducted on a tour through the plant of the Geometric Tool Co., while it was in operation. The visitors observed surface combustion furnaces, Bellis Lava Process and other interesting heat treating equipment which was in operation.

CINCINNATI CHAPTER

The Cincinnati Chapter held its regular monthly meeting on October 27th at 8:00 o'clock in the Ohio Mechanics Institute. The speaker for the evening was Mr. John H. Ames of the Lunkenheimer Company who gave a talk on "Pyrometers" which was a general discussion of the commercial types of pyrometers. Mr. Ames presented his subject in a very capable manner and an interesting discussion followed the presentation of his paper. The Cincinnati Chapter has outlined a very interesting course of papers for the coming season. The subjects that will be discussed during the year are: Blast Furnace and Pig Iron; Grading of Iron; Pig Iron for the Foundry; Autogeneous Welding; Metallurgical Furnaces & Fuels; Stainless Steel; Inspection of Foundry; Case Hardening; Auto Trip to American Rolling Mills, Middletown, Ohio; and finally the Annual Dinner and Meeting.

CLEVELAND CHAPTER

The Cleveland Chapter held its first monthly meeting October 17th in the Cleveland Engineering Society Rooms in the Hotel Winton. The paper for this meeting was presented by R. S. Archer, Metallurgist of the Aluminum Company of America. The title of Mr. Archer's paper was "The Slip Interference Theory of the Hardening of Metals". Mr. Archer presented his theory in a very clear and logical manner, and after the presentation of the paper a discussion of the theory was in order. There were many interesting questions asked Mr. Archer, and he was able to answer in a very convincing way points in objection to his theory. Dr. Jeffries and Mr. Archer are still working on this theory and it is hoped that we shall hear from them at a later date.

Mr. W. H. Eisenman, National Secretary of the Society, gave a brief account of the activities of the Detroit Convention. The next meeting

of the Cleveland Chapter will be held November 21 at which time the Cleveland Chapter will hold a joint meeting with the Cleveland Engineering Society, the Society of Mechanical Engineers and the Society of Mining and Metallurgical Engineers. Dr. John A. Mathews, President of the Crucible Steel Company of America, will present his paper entitled "Alloy Steels".

HARTFORD CHAPTER

The September meeting of the Hartford Chapter was held on Friday, Sept. 15. Mr. Stanley P. Rockwell addressed an audience of 72 on the subject of "Furnaces, their Design and Construction". A considerable portion of his talk was given up to the calculation of the efficiency of a furnace, and in the discussion of this phase of the problem, the electric furnace showed up best. The talk was illustrated by slides showing standard designs and methods of producing uniformity in large furnaces.

A short discussion on the subject of carburizing followed, in which the recent impact tests made by Mr. d' Arcambal were described. A resume was also given of the work of Ehn and McQuaid on irregularities in carburizing steel.

Mr. W. D. Fuller read abstracts of metallurgical and heat treatment articles which appeared in the technical and trade journals during the Summer.

During the meeting cards were passed out so that members might jot down questions that occurred to them while the speaker held the floor, and these were handed to the chairman for discussion afterward. Cards were also passed out to obtain the names, addresses, and company connections of those present. These cards were subsequently collected and thoroughly shuffled, then one card was drawn from the pile; the person whose card was drawn to receive a prize in the form of a book on heat treatment, a subscription to a metallurgical or heat treating journal, or, to non-members, a credit of one-half years dues in the society. The drawing was won by Mr. W. R. Bowes, who selected a subscription to "Forging and Heat Treating", to be circulated throughout his plant each month.

The meeting was then addressed by Mr. A. W. F. Green, the visiting chairman of the Philadelphia Chapter, who called for a square deal for the speakers at these meetings. After a man had spent some time in preparing a paper for a meeting, he was entitled to a chance to answer criticism, that is, if there was any criticism to be made of his paper, it should be made in open meeting, during the discussion, where the speaker would have a chance to defend himself and his views. Such discussion would make the meetings more helpful.

The October meeting of the chapter was held on October 13th, in the Hartford Electric Light Co. Hall. This hall is ideal for the purposes of the chapter, and the Electric Light Co. has kindly offered the use of it for the entire year.

The speaker of the evening was Mr. H. C. Goodwill, superintendent of the Die Department of R. Wallace and Sons, Wallingford. Mr. Goodwill gave a short talk covering the types of steel used for their various types of dies, described the heat treatment applied, and the heat

treating equipment used. After his brief talk, he called for questions, and spent over an hour on his feet thereafter answering the questions inspired by his talk. Without a doubt, this meeting was one of the most successful the chapter has had, judging by the interest shown in the discussion, in which the speaker amplified what he had already said, and added much more information requested by individuals in his audience.

Three questions, taken from those printed in the back of the "Transactions", were offered for discussion, as follows:

QUESTION NO. 1. What regulations are recommended to reduce the fire hazzard of quenching tanks?

QUESTION NO. 2. May tools be heat treated properly in a furnace in which copper is present?

QUESTION NO. 3. What is the difference between red annealed and blue annealed sheet steel?

1. It was suggested that an extinguisher system, such as the "Foamite" be installed. Or, another method suggested was to have a pumping system that would empty the oil into a cooling tank at some distance from the quenching tank.

2. The experience of those present seemed to indicate that the presence of copper would not affect the tools. Cases were cited where tools were copper-plated for engraving or other purposes, and then hardened. The parts coated with copper appeared to respond properly to the hardening treatment. A note on the vaporization of copper at heat treating temperatures recently appeared in Chemical and Metallurgical Engineering but no ill effects were reported.

3. While some difference of opinion existed, it was believed that the terms "Red Annealed" and "Blue Annealed" referred to the color of the scale on the annealed sheet. The blue or black scale usually results when the material is pack-annealed, and the red when annealed without packing. It was also remarked that high carbon steel shows a greater tendency toward coming out red after open annealing than the lower carbon steels.

The last feature of the evening was the drawing for the prize, using the attendance cards. Mr. Lanning was the winner of his choice of a number of heat treating books, or current publications.

INDIANAPOLIS CHAPTER

The regular monthly meeting of the Indianapolis Chapter was held in the Directors Rooms of the Indianapolis Chamber of Commerce, Monday evening, October 10th.

Preliminary to the regular meeting a short executive meeting was held.

At 8:00 the regular meeting was called to order by the chairman and a short business discussion followed. A committee was appointed with power to act in connection with having the next meeting a dinner meeting at the Hoosier Athletic Club.

Prof. John Keller of Purdue University spoke in connection with a proposed extension course which Purdue University hopes to establish

in conjunction with Indianapolis Chapter.

The meeting was then turned over to Mr. H. B. Northrup, Metallurgist for the Diamond Chain & Mfg. Co., who spoke on the subject of "Iron Ore and the Blast Furnace". His subject was illustrated by lantern slides loaned to him by Penn State College. His talk covered the subject from the early discovery of iron ore down to the present day practice. Mr. Northrup's paper was made all the more interesting because of the fact that he has worked personally in some of the mines.

The next meeting of the Chapter is to be held Nov. 13th and the subject will be "Practical Applications of Metallography". A microscope will be at hand to facilitate the study of the specimens.

LEHIGH VALLEY CHAPTER

The Lehigh Valley Chapter held a meeting on Monday evening, October 23rd, at Bethlehem Steel Company, Battery Building, Bethlehem, Pa. The speaker for this meeting was Mr. A. Koleser, of the Ingersoll-Rand Company. who discussed "Pyrometry". Mr. Koleser handled his subject in a very capable manner and developed a very interesting discussion at the conclusion of his paper.

MILWAUKEE CHAPTER

The Milwaukee Chapter of the American Society for Steel Treating held its October meeting on the 19th, at 8:00 p. m. at the Blatz Hotel. The paper of the evening was presented by Mr. R. J. Doty of the Sivyer Steel Casting Company. The subject of Mr. Doty's paper was "Some Developments in the Annealing of Steel Castings". Mr. Doty is a well known foundry man and his paper and discussion which followed were well worth hearing.

NEW YORK CHAPTER

The New York Chapter held its October meeting in the Merchants' Association Rooms, 9th floor of the Woolworth Building Wednesday, the 18th at 8:00 p. m. The program for this meeting was a paper by Mr. W. J. Merten, Metallurgist of the Westinghouse Electric & Mfg. Company of Pittsburgh, Pa. The title of Mr. Merten's paper was "The Heat Treatment of Helical Springs" especially applied to railway equipment. Mr. Merten has had many years of experience along this line and spoke with authority on the subject.

NORTHWEST CHAPTER

The first meeting of the Northwest Chapter for the ensuing year was held Tuesday evening October 17th at 7:30 p. m. in the Manufacturers Club rooms, 200 Builders Exchange, Minneapolis.

Norman Conn, Minneapolis Steel & Machinery Company, who with O. E. Harder attended the Detroit Convention of the National Society as delegates from this Chapter, reported upon what was accomplished at the convention and reviewed some of the plans that the National Society has decided upon to stimulate and encourage the activities in the various Chapters.

A three reel motion picture, produced by the Interstate Iron and

Steel Company of Chicago, entitled "The Making of Steel," was shown at this meeting for the second time in this country. It was first shown at the Detroit Convention where it was pronounced a distinct contribution to the science of steel treating as it presents the latests improvements and refinements in the art.

The meeting was well attended and a very enjoyable and profitable evening was had by all.

PHILADELPHIA CHAPTER

The Philadelphia Chapter held its September meeting Friday evening, the 29th, at the Engineers' Club. The program for the evening was entitled "Ten Talks on Philadelphia Topics" presented by several Philadelphia people. The topics which were discussed were as follows: Motion Pictures—"Some Steps in Building a Modern Locomotive" by Mr. Walter Adamson, Test Department, Baldwin Locomotive Works, Philadelphia; "The Old and New Heat Treater" by C. R. Carey, Sales Manager, Leeds & Northrup Company, Philadelphia; "Kinks in Heat Treating Furnaces" by Mr. F. A. Hall, Engineer, F. J. Ryan Co., Philadelphia; "Problems in Treating Steel for Auto Bodies" by Dr. Geo. L. Kelley, Metallurgist, Edward G. Budd Mfg. Company, Philadelphia; "Automatic Temperature Control" by Mr. R. P. Brown, President Brown Instrument Company, Philadelphia; "Tools and Production" by Mr. H. D. Vandegrift, Superintendent of Tools, Miller Lock Company, Philadelphia; "Steel and Philadelphia," by Mr. G. P. Bible, H. T. Potts Company, Philadelphia.

This meeting was very well attended, about 125 people in all.

The Philadelphia Chapter held a meeting on Friday evening, October 27th, at 8:00 p. m. in Engineers' Club rooms. The paper for this meeting was presented by Mr. Sam Tour, Metallurgist of the Doehler Die Casting Company, Brooklyn, N. Y., entitled "Salt Baths for Heat Treating." This paper proved to be very interesting and instructive and one which brought out considerable good, interesting discussion. Mr. Arthur L. Collins, secretary of the chapter, presented a paper entitled "Thermal Critical Points." Mr. Collins' paper likewise brought out considerable interesting discussion.

PITTSBURGH CHAPTER

The Pittsburgh Chapter of the Society held a meeting on October 10th at which time, Mr. W. J. Merten of the Westinghouse Electric and Manufacturing Company presented a paper entitled "The Development and Manufacture of Helical Springs for Flexible Drives". This meeting was well attended, and the discussion which followed Mr. Merten's paper was indeed interesting.

RHODE ISLAND CHAPTER

The first meeting of the Rhode Island Chapter for the year 1922-23 was held on October 18th at 8 p. m. in the rooms of the Providence Engineering Society. The paper for this meeting was presented by S. W. Parker, Metallurgist, Wheelock Lovejoy & Company, Cambridge, Mass. The subject of his paper was "The Manufacture of Steel." Mr. Parker's paper was indeed interesting and pointed out many of the difficulties which are encountered in the manufacture of steel.

ROCHESTER CHAPTER

The October meeting of the Rochester Chapter was held in the rooms of the Rochester Engineering Society October 9th. Mr. W. W. Lewis, of the Development Department of the American rolling Mills Company, Middletown, Ohio, lectured during the exhibition of the four reels of motion pictures taken at their plant which was entitled "The Rolling of Steel". This meeting was the second of a series of meetings dealing with steel and its heat treatment from the ore through to the finished product. The meeting was well attended and considable and valuable discussion was heard following the presentation of the film.

ST. LOUIS CHAPTER

On Monday evening, October 16th, the St. Louis Chapter held its regular monthly meeting in the American Annex Hotel. Prof. John F. Keller was the speaker of the evening. The subject of his paper was "Why Steel Warps". Professor Keller who is an expert along the line of steel treating presented his paper in a very clear and logical manner.

SCHENECTADY CHAPTER

The first monthly meeting of the Schenectady Chapter was held October 17th. The speaker of the evening was Mr. Paul Doerr of the E. F. Houghton & Company who spoke on "Principles and Applications of Carburizing, Quenching and Tempering Mediums". The meeting was very well attended, and following Mr. Doerr's paper a lively discussion took place. The Schenectady Chapter members are taking active steps to increase their membership so that they may advance their position in the standing of chapters list.

SOUTH BEND

The South Bend Chapter at the October meeting has, we believe, started an innovation in Chapter activities.

The October meeting was held on the 10th, at the Studebaker cafeteria, Plant No. 2. The meeting was started with several numbers rendered by a well known saxophone sextette. A brief business meeting was held, after which the members and guests present enjoyed several musical numbers received by radio at the meeting.

At 9:00 o'clock, Mr. W. E. Ruder, M. E. of the General Electric Co., Schenectady, N. Y., addressed the meeting on the subject, "The Fatigue of Metals." This address was received by radio, and everyone present was able to hear perfectly. This talk, of course, was broadcasted so that radio fans for miles around South Bend could listen in, the talk being general and not too technical. This, in addition to being a novelty, also gave much publicity to the South Bend Chapter and to the Society as a whole.

After the talk by radio, the speaker was brought back to the Studebaker plant, where he addressed the meeting on the same subject in detail, and by the use of slides.

A general discussion was held following this talk, after which the meeting was adjourned.

In view of the fact that on this day we had the most disagreeable weather,

we believe we had a very successful meeting, there being 75 members and guests present. Fully that many more stayed away due to the inclement weather.

The Chapter wants to go on record as favoring Cleveland for the next National Convention, providing Cleveland wants the Convention.

SPRINGFIELD CHAPTER

The Springfield Chapter held its second monthly meeting Friday evening, October 20th, in the Chamber of Commerce Building, at which time Mr. Geo. P. Moore, Metallurgist of Wallace Barnes Company, Bristol, Connecticut, delivered a paper entitled "Wire and Spring Manufacture and Treatment." Mr. Moore represents one of the largest spring companies in the East, and has specialized for many years on the metallurgy of spring manufacture and is considered an authority on steel springs. Following Mr. Moore's paper a very interesting discussion was held.

SYRACUSE CHAPTER

The Syracuse Chapter of the Society held its October meeting at the Yates Hotel Friday evening, October 13th. The program for this meeting was a moving picture film illustrating the "Manufacture of Sheet Steel." Mr. R. D. Black, Buffalo District Sales Manager of the American Rolling Mill Company, lectured during the exhibition of these pictures, as the pictures were taken at the plant of the company Mr. Black represents.

TRI CITY CHAPTER

The Tri City Chapter of the Society held a meeting on October 26th in the Davenport Chamber of Commerce at 8:00 p. m. The program for this meeting was a paper entitled, "Furnaces and Their Application in Heat Treatment" by W. C. Squire, Engineer of the W. S. Rockwell Company, New York City. Mr. Squire's paper was indeed interesting and developed some of the various designs in the different types of heat treating furnaces.

WASHINGTON CHAPTER

The September meeting of the Washington Chapter was held Friday, the 22nd at 8:00 p. m. in the Auditorium of the New Interior Department Building. The program for this meeting consisted of two sections of motion pictures, part 1--"The Manufacture of Tool Steel" by the Atlas Crucible Steel Company, Dunkirk, New York. This picture illustrated in detail the various operations incidental to the production of a high grade steel product and the extreme care necessary for successful accomplishment. Part 2 entitled "Uses and Abuses of Twist Drills" by the Cleveland Twist Drill Company, Cleveland, Ohio, illustrated the application of a particular type of tool to industrial processes, and illustrated those practices which frequently shorten the useful life of good tool steels incorporated into carefully made tools. This meeting was well attended, and all who were present had a very enjoyable, entertaining and instructive evening.

The October meeting of the Washington Chapter was held in the Auditorium of the New Interior Department Building at which time Mr W. J. Merten, Research Engineer of the Westinghouse Electric an:

Manufacturing Company, East Pittsburgh, Pa., presented a very capable paper entitled "The Development of Helical Springs for Locomotive Flexible Drives". Mr. Merten has had extensive experience in the development of heat treatment practice as applied to large size coil springs, particularly for railway service. While these problems closely parallel those encountered in the preparation of heavy springs for ordnance purposes, there are essential differences in the relative importance of the cost of material, cost of manufacture, load tolerances, etc. Mr. Merten developed his subject in a very comprehensive manner, and it was followed by an interesting discussion.

Question Box

(*Continued from Page* 255)

QUESTION 50. *What is the chemical composition of the so-called "stainless steel" used for cutlery purposes?*

ANSWER. According to the latest information we have on the subject, the analysis, that is recommended for stainless steel to be used in cutlery manufacturing is as follows: Carbon .30 to .45 per cent; Chromium 13 to 16 per cent; Phosphorus and Sulphur below .03 per cent; Silicon .30 per cent; and Manganese .50 per cent.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A repesents Associate Member; S represents Sustaining Member; J represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

NEW MEMBERS

ABBOTT, J. H., (M-9), 1969 Seward Ave., Detroit, Mich.
ADAMS, W. E., (A-10), 12 Sigourney St., Boston, Mass.
AFFLECK, G. S., (M-9), 278 E. Canfield Ave., Detroit, Mich.
ALLA, E. S., (M-10), 13530 Thomson Ave., Highland Park, Mich.
ALLINGTON, A. L., (M-10), 132 Cedar St., Wyandotte, Mich.

BAILY, T. E., (A-10), R. F. D. No. 1, Alliance, Ohio.
BATIE, J. E., (M-10), 3615 Military Ave., Detroit, Mich.
BEAN, L. G., (A-10), 514 Old South Bldg. Boston, Mass.
BENNETT, A., (M-10), 29 Little Ave., Weston, Ont., Can.
BENNETTS, E., (M-10), 5929 Commonwealth Ave., Detroit, Mich.
BLACKBURN, C. J., (M-9), 52 Garfield Ave., Detroit, Mich.
BLACKINGTON, R. C., (M-10), C. H. Wills & Co., Marysville, Mich.
BRAY, W. J., (M-10), 311 Chestnut St., St. Paul, Minn.
BRUCE, A. J., (A-11), 132 E. Woodbridge St., Detroit, Mich.
BURKEMER, M. E., (A-10), 333 Frankfort Ave., Cleveland, O.
BUTT, H., (M-10), 1156 Leader-News Bldg., Cleveland, O.

CAMPBELL, J. F., (M-10), Amer. Malleables Co., Lancaster, N. Y.
CARPENTER, C. B., (M-10), Colorado School of Mines, Golden, Colorado.
CHAMBLISS, G. S., (M-10), Tool Steel Gear & Pinion Co., Cincinnati, O.
CHERNISKI, A. L., (M-10), 3258 Hanley Ave., Hamtramck, Mich.
CHERRY, R. M., (M-10), 1003 Nott St., Schenectady, N. Y.
CHESTERFIELD, P., (M-10), 261 St. Aubin Ave., Detroit, Mich.
CHRISTIAN, R. E., (M-10), 230 Elmhurst Ave., Highland Park, Mich.
COLEMAN, S. C., (M-9), Rich Steel Prod. Co., Battle Creek, Mich.
CONN, N., (M-10), 3200 Calhoun Ave., Minneapolis, Minn.
COOLEY, A. C., (M-10), General Elec. Co. Research Laboratory, Schenectady, N. Y.
COWAN, P. J., (M-10), National Malleable Co., Front St. and Payne Ave., Toledo, Ohio.
CUMMINGS, E. E., (M-10), Delco Light Co., Dayton, Ohio.

DAVIS, H. H., (A-10), 6 Sorrento St., Springfield, Mass.
DAWSON, R. T., (M-10), Adams Axle Co., Finlay, O.
DE HAVEN, H. E., (M-10), 8114 Lawton Ave., Detroit, Mich.
DEMERS, I. J. B., (M-10), 441 Stryker Ave., St. Paul, Minn.
DEUBLE, N. L., (M-10), 1408 N. Cleveland Ave., Canton, Ohio.
DIETZ, C. W., (M-10), 112 E. Dayton St., South Bend, Ind.
DOWNES, T. W., (M-10), 2524 S. 19th St., Philadelphia, Pa.
DUNN, L. C., (A-10), Montgomery Chem. Wks., Detroit, Mich.
DUNSMORE, R. E., (M-10), 4119 S. Western Ave., Los Angeles, Cal.

EDWARDS, S. H., (M-10), Muncie Prod. Div., Muncie, Ind.

FAWLEY, A. E., (M-10), 3710 Hamilton St., Philadelphia, Pa.
FINDLATER, J. J., (M-10), 100 Tuxedo Ave., Highland Park, Mich.
FOX, JOHN, (M-10), Henry Clay Hotel, Detroit, Mich.

GARDNER, G. E., (M-10), 2278 Detroit Ave., Toledo, O.
GINKEL, F., (M-10), Marseilles Works, Deere Company, E. Moline, Ill.
GOLLY, F. B., (M-9), Y. M. C. A., Detroit, Mich.
GRAVES, W. H., (M-10), Packard Motor Car Co., Detroit, Mich.
GREENE, H. L., (M-8), 1434 Lincoln Ave., Toledo, O.
GRIGGS, E. R., (M-10), Lufkin Rule Co., Saginaw, Mich.
GRISWOLD, H. C., (M-11), Blackburn Pl., Summit, N. J.

HAGBERG, O. F., (M-10), 26 Salisbury St., Worcester, Mass.
HAISLIP, R. E., (M-9), 1291 Fairview, Detroit, Mich.
HAMILTON, D. W., (M-9), 1115 W. Allegan St., Detroit, Mich.
HARVEY, D., (M-11), 109 Dewey Ave., Pittsburgh, Pa.
HASSIG, E., (M-10), 247½ 18th St., Milwaukee, Wis.

HAYES, T. D., (M-10), Central Steel Co., Massillon, O.
HEALY, J. A., (A-10), 1504 Methyle St., Beachview, Pittsburgh, Pa.
HEISER, L. W., (M-10), 4919 Ogden Ave., Detroit, Mich.
HERMANN, E., (M-12), R. H. Hassler, Inc., Indianapolis, Ind.
HOKANSON, M., (M-10), Marshall-Wells Co., Duluth, Minn.
HOLTON, H. L., (M-10), Advance Rumely Co., Battle Creek, Mich.
HUNGELMANN, A., (M-10), 345 Pierce St., Gary, Ind.

IRELAND, D. B., (M-11), Ireland & Matthews Mfg. Co., Detroit, Mich.

JACOBSEN, A. E., (Jr.-10), 1265 75th St., Brooklyn, N. Y.
JONES, D. J., (A-10), 3319 Park Ave., Indianapolis, Ind.
JUTHE, K. A., (A-10), 149 Tremont St., Boston, Mass.

KAHN, N. H., (M-10), 452 Birkle Ave., Bethlehem, Pa.
KEENEY, R. M., (A-10), Westinghouse Electric & Mfg. Co., Boston, Mass
KELLER, F., (M-10), No. 1 Prevost Ave., Keyport, N. J.
KERR, R. B., (M-10), 919 43rd St., Rock Island, Ill.
KING, W. C., (M-10), 1135 Main St., Bethlehem, Pa.
KLEMZ, C. W., (M-10), Riter-Conley Co., Leetsdale, Pa.
KLINE, C. B., (M-10), 1524 Dormant Ave., South Hill Sta., Pittsburgh, Pa.
KOTTNAUER, E. H., (A-10), Crucible Steel Co. of America, Detroit, Mich.
KUENY, A. A., (M-10), Studebaker Corp., Plant No. 5, Detroit, Mich.
LARIME, E. J., (M-8), 5144 Belvidere Ave. Detroit, Mich.
LEFFLER, W. W., (M-10), Central Steel Co., Massillon, O.
LEDIN, J., (M-10), 2210 Giddings St., Chicago, Ill.
LEE, H., (A-10), 383 Concord Ave., New York City.
LEE, I. H., (M-8), 1439 W. Grand Blvd., Detroit, Mich.
LESPERANCE, L. J., (M-10), 1206 Beniteau Ave., Detroit, Mich.
LINDSEY, W. M., (M-10), 317 N. Lincoln Ave., Massillon, O.
LOUDENBACK, C. I., (A-10), 2407 1st Nat'l Bk. Bldg., Detroit, Mich.

MACFARLAND, A. F., (S-11), 5219 Trumbull Ave., Detroit, Mich.
MACGREGOR, I., (M-10), Sanderson Brothers, Sheffield, England.
MANN, E. O., (M-10), 2626 Northwestern Ave., Detroit, Mich.
MANN, M. A., (A-10), 8243 Wilson Ave., Detroit, Mich.
MAREMONT, M. O., (M-10), Maremont Mfg. Co., Chicago, Ill.
MARLOW, J. S., (A-8), 7 Mayflower Apts., Indianapolis, Ind.
MATHEWSON, C. H., (M-10), Yale University, New Haven, Conn.
McADAM, D. J., (M-10), Naval Engr. Experimental Sta., Annapolis, Ind.
McCABE, J. C., (M-10), Dept. Safety Engr., City Hall, Detroit, Mich.
McCLUNG, H. F., (M-10), Studebaker Corp., Plant No. 3, Detroit, Mich.
McDONALD, J. A., (M-8), 4501 Mt. Clair Ave., Detroit, Mich.
McINNES, COLIN, (A-10), Colonial Steel Co., Pittsburgh, Pa.
McKENZIE, E. M., (M-11), 5909 Quimby Ave., Cleveland, O.
McMULLAN, O. W., (M-10), 2942 Cass Ave., Detroit, Mich.
MITCHELL, D. E., (M-8), 2377 E. Grand Blvd., Detroit, Mich.
MORGAN, J. J., (M-10), Naval Air Station, Hampton Roads, Norfolk, Va.
MORGENTHAU, WM., (M-8), 2664 Eastlawn Drive, Flint, Mich.
MOSS, H. W., (S-10), 545 Book Bldg., Detroit, Mich.
MUNN, C. G., (M-10), Amer. Twist Drill Tool Co., Detroit, Mich.

NESSER, J. O., (M-10), 7620 Kipling Ave., Detroit, Mich.
NIERODT, W. J., (M-10), 262 National St., Elgin, Ill.
NORTHRUP, H. M., (M-8), Hudson Motor Car Co., Detroit, Mich.

OLDHAM, E. L., (M-11), 3734 E. 78th St., Cleveland, Ohio.
OBERTING, CHAS., (M-4), 1134 Kelly St., Indianapolis, Ind.
ODEMAR, F. W., (A-9), 305 Merchants Bk. Bldg., Indianapolis, Ind.

PARSONS, J. C., (M-9), American Auto Parts Co., Detroit, Mich.
PECKHAM, E. G., (M-10), Armstrong Spring Co., Flint, Mich.
PETERSON, A. K., (M-7), 224 Summit St., Rockford, Ill.
PETERSON, J. W., (M-11), 448 Underwood St., Rockford, Ill.
PLAGE, WM., (A-11), 87 Vermont St., Brooklyn, N. Y.
POTTER, O. D., (M-10), 653 Flint Park Blvd., Flint, Mich.
PROCTOR, C. H., (A-9), Roessler & Hasslacher Chem. Co., New York City.

RICHARDS, W., (M-10), 414 Pawnee St., Bethlehem, Pa.
ROBINSON, A. H., (M-10), 45 Mathews St., Pontiac, Mich.
ROGERS, C. R., (M-9), C. L. Best Tractor Co., San Leandro, Cal.

ROLF, R., (M-9), 1160 E. 74th St., Cleveland, Ohio.
ROSS, WM. H., (Jr.-10), 6465 Trumbull Ave., Detroit, Mich.
ROWDEN, C. S., (M-10), 587 Summer Ave., Newark, N. J.
RUPPEL, W. A., M-10, Firth-Sterling Steel Co., New York City.

SAGAR, E. S., (M-10), Kelsey Wheel Co., Inc., Detroit, Mich.
SANDMEYER, J. E., (M-10), Youngstown Sheet & Tube Co., Youngstown, O.
SATOH, K., (M-10), Tokyo Galvanizing Co., Ltd., Tokyo, Japan.
SCARBROUGH, H. E., (A-10), General Elec. Co., Chicago, Ill.
SCHEID, A. J., (M-10), 137 Sycamore St., Milwaukee, Wis.
SCHERMER, N. H., (A-9), 55 Colorado Ave., Highland Park, Mich.
SCHOESSEL, C. A., (M-10), John Deere Harv. Co., E. Moline, Ill.
SECOR, J. M., (M-10), Ingalls Shepard Division, Wyman Gordon Co., Harvey, Ill.
SHAFER, W. H., (M-11), 2879 Erie Ave., Cincinnati, O.
SHEPARD, R. L., (M-10), 141 Montana W. Detroit, Mich.
SINCLAIR, C. E., (M-10), 3615 Military Ave., Detroit, Mich.
SMITH, A. J., (M-10), 4210 Van Dyke Ave., Detroit, Mich.
SMITH, S. S., (A-10), 620 E. Hancock St., Detroit, Mich.
SPENCER, M. P., (A-10), 608 W. Adams St., Chicago, Ill.
SPIEGEL, H. W., (A-8), 1776 W. Lafayette Blvd., Detroit, Mich.
STALLKAMP, R. F., (M-10), 4044 Commonwealth Ave., Toledo, Ohio.
STARGARDTER, A. R., (M-9), Marlborough Apts., Baltimore, Md.
STEPHENSON, R. L., (M-10), 964 Stimson Pl., Detroit, Mich.
STEVENS, D., (M-8), 2236 Garland Ave., Detroit, Mich.
STUCK, H. D., (M-10), 184 Abbott St., Lawrence, Mass.

TAYLOR, J. W., (A-10), 2009 Oliver Bldg., Pittsburgh, Pa.
TEEL, H., (A-10), 4110 Helen Ave., Detroit, Mich.
TERWILLIGER, E. S., (M-11), 163 N. Hamilton St., Poughkeepsie, N. Y.
THORPE, C. N., (M-10), Bagshaw & Field, Ltd., Philadelphia, Pa.
TOMPKINS, C. S., (S-10), 1219 Dime Bk. Bldg., Detroit, Mich.
TOMSETT, G. F., (M-10), 6026 Maxwell Ave., Detroit, Mich.

VANDERGRIFT, H. D., (M-10), 4638 Richmond St., Bridesburg, Pa.
VAN CLEVE, A. E., (M-11), 56 S. Maple Ave., E. Orange, N. J.
VAN DALSON, E. S., (M-10), Dodge Bros., Detroit, Mich.
VINCENT, R. E., (M-5), 3131 Bellevue Ave., Detroit, Mich.
VOORHEES, E. C., (M-9), Erie Forge Co., Erie, Pa.

WADHAMS, A. J., (S-10), International Nickel Co., New York City.
WALLIS, W. B., (M-10), Pittsburgh Elec. Furnace Corp., Pittsburgh, Pa.
WALKER, W. G., (M-10), 9601 American Ave., Detroit, Mich.
WALLS, F. J., (M-10), Wilson Fdry. & Mach. Co., Pontiac, Mich.
WEAVER, H. A., (A-10), Box 205, Carnegie, Pa.
WEBB, GEORGE, (M-11), 189 S. Whitney St., Hartford, Conn.
WEISS, H. S., (M-10), Sun Inn, Philadelphia, Pa.
WELLES, H. M., (M-10), Commercial Truck Co., Philadelphia, Pa.
WELSH, L. E., (M-10), 602 Penfield Bldg., Philadelphia, Pa.
WING, J. F., (M-10), 149 Tremont St., Boston, Mass.
WOOD, C. J., (A-10), 1443 Rosemont Ave., Chicago, Ill.
WOOD, L., (A-10), 809 Keystone Bldg., Pittsburgh, Pa.
WOODWARD, E. L., (M-10), 2201 Woolworth Bldg., New York City.

YOUNKINS, J. B., (M-10), 6472 Van Dyke Ave., Detroit, Mich.

ZAUCK, W. J., (M-10), R. No. 1, Trenton, Mich.
ZWAHL, C. E., (M-10), 27 E. Willis Luilado Apt., Detroit, Mich.

CHANGES OF ADDRESS

ASTIE, L. R., from Box 130, Freeport, to 3502 Parkview Ave., Pittsburgh, Pa.
BARR, WM., from Hughes Tool Co., Los Angeles, to Regan Forge & Engr. Co., San Pedro, Cal.
BEAUDRY, R., from Mineral St. to 752 Washington St., Milwaukee, Wis.
BEELER, C. F., from 2066 E. 89th St. to 12005 Fairport Ave., Cleveland, O.
BIERMAN, G. H., from Nela Park Lab. to White Motor Co., Cleveland, O.
BLOXTON, A. M., from Chesapeake St. to Bureau of Standards, Washington, D. C.
BOLDUC, E. N., from Mills St. to 127 Wilcox Ave., Bristol, Conn.

BOSTWICK, H. C., from Newark Ave., Elizabeth, to 35 Sprence St., Cranford, N. J.
CARLSON, T., from Thomas St. to 1107 N. Leamnigton, Chicago, Ill.
CHABOT, J. M. T., from Dwight St., New Britain, Conn., to 23 Silver St. Suite 8, Waterville, Maine.
CLARK, H. H., from 225 Maple Ave., Oak Park, to 1501 Spencer Ave., Wilmette, Ill.
DUNHAM, G. S., from 39th and Gilpin Sts. to 1601 32nd Ave., Denver, Colo.
EVANS, F. J., from State St., Springfield, Mass., to 366 Gerard Ave., New York City.
FLOOD, W. E., from W. 73rd St., Chicago, to 1015 Mapleton, Oak Park, Ill.
GROSSMANN, M. A., from Electric Alloy Steel Co. Charleroi, Pa., to Atlas Steel Corporation, Dunkirk, N. Y.
GRAVELIN, A., from Slocum Ave. to 529 Gifford St., Syracuse, N. Y.
HARMON, B. G., from Watervliet Arsenal to 6 N. Michigan Ave., Chicago, Ill.
HARTMAN, from Chamber of Commerce Bldg. to 1146 Morse Ave., Chicago, Ill.
HOOD, H. T., from 4th Ave., Detroit, Mich., to 115 S. Pennsylvania Ave., Greensburg, Pa.
HOYT, S. L., from Brown Ave., Willoughby, O., to Research Laboratory, General Electric Co., Schenectady, N. Y.
HOLLANDER, J. A., from Menasha Mach. Mfg. Co., Menasha, Wis., to 1613 Humboldt Blvd., Milwaukee, Wis.
JOSEPH, C. F., from W. Ionia St., Lansing, Mich., to 630 S. 4th Ave., Saginaw, Mich.
KELLER, J., from Lewis Institute, Chicago, to Purdue University, Lafayette, Ind.
KEIDEL, E. E., from W. 97th St. to 1080 E. 141st St., Cleveland, O.
KINGSBURY, J. A., from Leland Ave., South Bend, to 503 W. Third St., Mishawaka, Ind.
KNAPP, J. H., from Fifth St., Santa Monica, to 769 S. Central Ave., Los Angeles, Cal.
KOEPPEN, E. W., from Warren Ave. to 1944 Adams St., Chicago, Ill.
LEWIS, C. B., from Canfield Ave. to 42 E. Willis Ave., Detroit, Mich.
MACKENZIE, W. J., from Blackstone Ave. to 5437 University Ave., Hyde Park Sta., Chicago, Ill.
MATHUR, P. N., from Florence Ave. to 251 Garrison, Dearborn, Mich.
McBURNEY, J. W., from West Tech. High School to Cleveland Board of Education, 6th and Rockwell, Cleveland, Ohio.
McINERNEY, W. I., from Crucible Steel Co. to Box 221, Midland, Pa.
MULL, E. K., from Y. M. C. A. Bldg., Rochester, N. Y., to 219 Apsley St., Philadelphia, Pa.
MULL, H. C., from Michigan Ave., Chicago to c/o Warren Tool & Forge Co., Warren, O.
MURDO, E. E., from Park Mfg. Co., St. Paul, to 276 Emerson Ave., Minneapolis, Minn.
NICKERSON, FRANK, from Midvale Steel & Ordnance to 10 Hastings Terrace, San Francisco, Cal.
NOVAK, A., from Kennedye Ave. to 10706 Mt. Auburn Ave., Cleveland, Ohio.
OVENS, WM., from Birmingham to 4 Croft St., Galashiels, England.
PECK, C. A., from Monroe St. to 508 S. Rush St., South Bend, Ind.
PHILLIPS, W. W., from Glenwood Ave. to 89 Bedford St., Rochester, N. Y.
RIECKEL, WM., from Whittelsly Ave. to 28 N. Elm St., Wallingford, Conn.
RIEGER, W. H., from Sizer Forge Co. to 89 Donaldson Rd., Buffalo, N. Y.
ROBERTS, J. H., from Electric Alloy Steel Co., Youngstown, O., to Atlas Steel Corporation, Dunkirk, N. Y.
RODNEY, K. R., from Highland Iron & Steel Co., Terre Haute, Ind., to Chrome Steel Works, Chrome, N. J.
ROOT, H. H., from Barnard Ave., Watertown, to 259 Newbury St., Boston, Mass.
SPELIE, J. E., from Harvard Ave. to 4144 Clarendon Ave., Chicago, Ill.
STIVERS, L. C., from Bettendorf, Iowa, to 3 East State St., Davenport, Iowa.
SWANSON, O. V., from Elm St., Indiana Harbor, Ind., to 6526 Ellis Ave., Chicago, Ill.
THOMSON, W. G. H., from 37th St., Chicago, to P. O. Box 197, Wilkes Barre, Pa.

(*Concluded on Page* 276)

EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

Important Notice.

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITION WANTED

REPRESENTATIVE-SALESMAN. Eight years experience in selling steel products such as alloy and tool steels, bars, plates, shapes, axles, wheels and tires, and miscellaneous forgings. At present in charge of sales of forgings, wheels, tires, tool and alloy steels in the Pacific Coast Territory for large steel concern. Would like to correspond with steel company desiring a capable representative on the Pacific Coast. Address 10-1.

METALLURGIST or CHEMIST. Exceptionally good experience together with a record of absolute satisfaction. Available at once. Eastern location preferred. Address 10-5.

CHEMIST and HEAT TREATER. Technical graduate. Experience in chemical, physical testing and heat treating of steels. Eastern location preferred. Reasonable salary. Address 10-10.

WANTED by a practical man with 22 years' experience with some leading firms of the United States. position as Supervisor or foreman of Heat Treating. Address 8-5

METALLURGIST—desires position. Experienced and technically trained in chemical analysis, physical testing, microscopic work and heat treating of carbon and alloy steels. Address 11-5.

YOUNG MAN with four years experience in the heat treatment of steel and who has taken a course in metallography, wishes a position with some concern where there is a chance for advancement. Best of references. Address 9-1.

GRADUATE CHEMIST who has had several years' experience in metallurgical analysis, analysis of iron and steel, etc. His work will be for the present, at least, wholly analytical. Address 10-20.

POSITIONS OPEN

POSITION OPEN as Assistant Metallurgist with large plant making bearings. College graduate with some years practical experience in heat treating or steel mill work preferred. State in reply education, experience, and salary desired. Address 9-5.

WANTED—In tool and alloy steel research department 1921-1922 technical graduate who has specializvd in iron and steel metallurgy. Duties include running experimental melting furnaces, oil and electric; heating furnaces; and wide range of general work. Position offers good opportunity for future. Address 7-13

UNUSUAL opportunity to secure exclusive sales agency for tool steel mill in Detroit and Los Angeles districts. Mill long established and products of proven quality. Would require experience in selling steel and moderate capital. Address 9-15.

WANTED A MAN—to take charge of heat treating department in an eastern city. An expert metallurgist is not a requirement for this position but a man who is familiar with carburizing and general heat treatment routine. Address 11-15.

WANTED—A single man, graduate of technical course, and with either shop or steel mill experience to represent high grade alloy steel manufacturer with warehouse facilities. The representative would be placed in Milwaukee and would cover the territory in that vicinity under the direction of the Chicago branch. An excellent opportunity for young man who desires to work up as a sales representative. Address 11-10

WANTED—Metallurgist with mature experience in the melting and casting of nickel-chromium alloys. Permanent position offered by established concern Erecting new plant shortly. Address 11-20.

ANALYTICAL CHEMIST thoroughly familiar with the analysis of steel and steel works materials. Write, stating age, experience and salary required. Address 10-15.

(*Continued from Page* 275)

WICKENDEN, T. H., from Newark, N. J., to International Nickel Co., New York City.
WILLIAMS, C. C., from Bowen Prod. Corp. to 5017 32nd St., Detroit, Mich.
WILLIAMS, H. R., from Electric Alloy Steel Co., Philadelphia, to Atlas Steel Corporation, Dunkirk, N. Y.

MAIL RETURNED

BUFFINGTON, WM., 250 Ramsey St., Philadelphia, Pa.
EDELIN, J. W., 311 Fourth St., Washington, D. C.
PHILLIPS, J. W., 87 South 14th St., Newark, N. J.
TRAVIS, CHAS., 718 18th St., Rock Island, Ill.
WOLNICK, H. F., 2231 San Jose Ave., Chicago, Ill.

TRANSACTIONS

of the

American Society for Steel Treating

Vol. III Cleveland, December 1922 No. 3

GOOD ADVICE

WE ARE pleased to note an editorial published in the November issue of the *Railway Mechanical Engineer,* in which it was pointed out that the railroads of the country are not profiting as much as they should from the results of the activities of certain technical Societies and especially the American Society for Steel Treating. This editorial pointed out that considerable numbers of the papers presented at the annual convention of the American Society for Steel Treating held in Detroit and much of the discussion pertained to the production, forging and heat treating problems which are seldom presented to railway men, and that a large amount of the information which was brought out would prove of immense value when applied to ordinary railroad practice. Simply because railroad shops are operated for the most part as repair units is no reason why they should not be conducted on a business basis, and no modern business man, doing as much forging and heating work as the mechanical department men on the railroads do, would miss an opportunity to attend the conventions mentioned and keep in touch with the latest thoughts along forging and heat treating lines.

It was pointed out that the railroads should encourage their blacksmith foremen, heat treaters and forging experts to become members of the American Society for Steel Treating, and attend these conventions in order that they may benefit by hearing the papers on case-hardening, heat-treating, furnace construction, flow of metal under pressure, etc. The information which they would bring back to their shops and incorporate in local shop practice at the earliest possible opportunity would unquestionably save the railroads large amounts of money annually. These men should be allowed time and expenses for the trip, as is done by industrial concerns, because while it is true that the men benefit personally by the information and knowledge obtained, a far greater benefit accrues to the railroad which uses their knowledge. While all this is largely "water over the dam" as far as this year's conventions are concerned, responsible mechanical departmental officers should consider whether they have not missed a valuable opportunity to save money for the railroads by too rigid limitation of expense accounts. It has been suggested that steps should be taken to insure a good representation of railroad men at the American Society for Steel Treating convention next year.

One could count on their fingers the number of railroad men who are members of the American Society for Steel Treating. And this is not at all because they have not been approached on the subject but it is due largely to their indifference in the matter of accepting new ideas and profiting

thereby. It can be conservatively stated that more than a million dollars per year are wasted by the railroads through the use of dilapidated shop forging and heat treating equipment, thus depriving the shopmen the use of up-to-date equipment in the pursuance of their daily tasks. Therefore we, too, feel the American railroads could benefit very largely by studying the work that has been done recently in the use of alloy steel and thus lighten to a material extent the dead weight of their rolling equipment by the use of heat-treated alloy steels.

NATIONAL COMMITTEES

THE attention of the membership is directed to the National Committees appointed by President Lynch and published on page 28 of the TRANSACTIONS. In some committees there has been no radical change in the personnel, particularly in the Publication committee where the valuable services of the members have been continued.

President Lynch from his experience as chairman of the Standards committee last year has completely remodeled it and established a committee along larger lines. In the past, the committee has been composed of three members and while they have done very valuable work in formulating a program the committee was found too small to accomplish desired results, consequently, this year it has been enlarged until at the present time it has 26 members with Robert M. Bird, Engineer of Tests, Bethlehem Steel Company, as general chairman.

The committee is divided into four Sub-Committees on Recommended Practices: (1) for the heat treatment of tool steel; (2) for the heat treatment of steel—general (not including tool steel); (3) on case hardening; (4) on pyrometry.

The Chairman of each of the sub-committees together with the General Chairman form the governing board of the committee. One of the interesting things to note with reference to the President's new plan for this committee is that the members of each of the sub-committees have been selected from the same territory which will of course facilitate more frequent meetings.

The A. S. S. T. has every reason to be proud of the 294 members serving on more than 40 technical and administrative committees in the preparation of standards, reports, professional papers, meetings, research work and the dissemination of literature for the advancement of the metallurgical profession and the steel industry. Of this number, 146 are on national committees and 148 are serving on local committees.

The average member of the A. S. S. T. believes that true values are not measured by what he gets but by what he gives and that men of varying attainments, who have been more or less fortunate in the world are glad of the opportunity to share their success with others.

This is indicated by the fact that President Lynch did not receive a single refusal from any member whom he appointed upon his committees. It has been this wonderful spirit that has brought the Society to the front ranks of the profession it represents and with the continuation of this unprecedented co-operation great achievements will result from the work of the A. S. S. T.

COMPARISON OF AMERICAN AND ENGLISH METHODS OF PRODUCING HIGH GRADE CRUCIBLE STEEL

By T. Holland Nelson

SWEDISH iron in its natural condition containing, as it does, approximately 0.05 to 0.15 per cent carbon was of little use as a tool steel and to convert this, or in other words, to introduce a higher percentage of carbon, the soft bars were packed in alternating layers with charcoal into a converting furnace. This process is nothing more than a form of case hardening. The carbon content and the depth of penetration are entirely controlled by time and temperature. The average cementation furnace would take approximately three or four days to reach a temperature of 950 to 1000 degrees Cent. (1740 to 1830 degrees Fahr.) For ordinary mild heats this temperature would be maintained for six to seven days and for the hardest or razor steel temper anywhere from 11 to 14 days, and, occasionally, to obtain what is known as double converted bar some of the hardest material would be put in again and submitted to the same operation. After allowing the furnace to cool down, the bars were withdrawn and graded by the fracture into the varying degrees of hardness, which, of course, is correlative to either the depth of penetration or the carbon content.

As an example a converted bar was selected and after cleaning the scale from the bar, a series of chips were taken with a planing machine. From the outside to the center 12 cuts were taken, each having a depth of 0.02 inch, then in each cut the carbon was determined. The results obtained were:

Cut No.		Depth into Bar In.	Mean Carbon Content
1	Outside	.02	.98 per cent
2	"	.04	.95 "
3	"	.06	.76 "
4	"	.08	.63 "
5	"	.10	.50 "
6	Medium	.12	.39 "
7	"	.14	.37 "
8	"	.16	.31 "
9	"	.18	.18 "
10	"	.20	.15 "
11	"	.22	.10 "
12	Centre	.24	.10 "

The mean carbon in the half bar (of mild No. 2 bar) was .45 per cent.

It will now be seen why it is impossible to determine the carbon by chemical analysis. The carbon is not evenly dispersed throughout the bar.

It will be readily appreciated that by this process it was impossible to obtain material uniform from outside to center and to reduce this lack of uniformity to a negligible quantity the bars were taken in fives (or what was known as faggoted), heated to a welding heat and forged together. During the heating the faggot was repeatedly smothered with a flux composed of lime, borax and salt, to prevent oxidation and to assist the welding. After a satisfactory weld had been obtained the bar was bent over, or sheared, and again rewelded to itself. This was known as shear steel. If again sheared and welded to itself the material is known as double shear steel, signifying

---

A paper presented before a meeting of the Society. The author, T. Holland Nelson, is manager of Henry Disston & Sons, Inc., Philadelphia.

Acknowledgement is made to *Raw Materials* for the use of the cuts illustrating this paper.

that after welding it had been either sheared or twice sheared.

It was at this period of the tool steel industry that Benjamin Huntsman

Fig. 1—Interior Crucible Furnace, "Teeming."

revolutionized it almost as completely as Taylor and White did at a later date when they perfected Robert Mushet's high-speed steel. Sheffield tradition

has it, and we have reason to believe this tradition to be correct, that Benjamin Huntsman was a maker of watch and clock springs, and having trouble with these springs, like many other people, (even today) he became so convinced of the correctness of his methods that he turned his attention to the steel and blamed the steel for all his troubles. In this respect, perhaps, we have many Benjamin Huntsmans still left. With a series of laminated bars of varying degrees of hardness there would be a distinct lack of uniformity which must have a bearing upon such delicate articles as clock and watch springs.

Huntsman carefully studied the then known methods of production such as has been outlined and conceived the idea that if it were possible to get the blister bar molten and poured into one solid mass the carbon would automatically become uniformly diffused and his watch and clock spring troubles thus be at an end. Finding little if any support for his theory among the local tradesmen he set to work to manufacture his own steel and he took as his base, blister bar broken up in small pieces, placed into an ordinary clay crucible, and melted by coke. From this early inception of the crucible process many improvements, modifications, and in some cases dangerous departures have been made. Huntsman's secret, as all other secrets, eventually leaked out and crucible steel today can claim many advantages over the original shear and double shear steel, but there are still some cases where the old fashioned article is found superior to the crucible steel, for it is not difficult to understand that with shear steel it was possible to obtain, owing to the irregular distribution of its carbon content, high carbon steel backed up by milder steel, or a combination of hardness and toughness so finely dispersed owing to the numerous welds that it is impossible to obtain by any other method. The nearest approach to it today is the variety of combined iron and steel sections used for different purposes where both hardness and toughness are required.

The coke-fired furnace and the clay pots were rapidly adopted in Sheffield. Some few gas-fired furnaces such as you have in this country have found their way into Sheffield, but the plumbago pot has not seriously been taken up. I can safely say that 80 per cent of the crucible tool steel, made in Sheffield is produced in coke-hole furnaces using clay pots.

Fig. 8 illustrates the method by which clay crucibles are made in Sheffield. A clay pot is made from a mixture of fireclay similar to the following:

Fig. 3—Water-wheel race at Clay Wheel Forge.

	No. 1.	
5½	bags	Derby clay
2½	bags	Common clay
3½	bags	China clay
170	lb.	Coke dust
	No. 2.	
6	bags	Derby clay
3½	bags	China clay
1½	bags	Common fireclay
160	lb.	Coke dust
	No. 3.	
5	bags	Derby clay
3½	bags	China clay
2½	bags	Common clay
160	lb.	Coke dust

These materials are mixed together with water, as far as possible with a shovel and then submitted to what is known as treading. This is done with

the bare feet and continued for periods up to two hours. Sheffield is a great place for individual prejudice; each particular pot maker has his own particular mixes of clay, his own idea of how much coke dust should go into the mix and a stipulated time when he will add water. In fact, he attempts to surround his own particular job with as much mystery as possible in the hope that should you at any time "fire" him the firm will go out of business. I have never known of this happening, but the attitude of the operatives contrasts sharply with the open and frank way in which the writer has always found matters discussed in this country. The clay is made into a ball and then dropped into a flask; a plug is then hammered (Fig. 9) with a wooden hammer into the material, and the shape thus formed. The moist clay pot is forced out of the flask by means of a ram and the incurve at the top formed by using a small hand dish.

Fig. 2—Dam at Clay Wheel Forge.

The pots are taken invariably to the back of the crucible furnace stacks

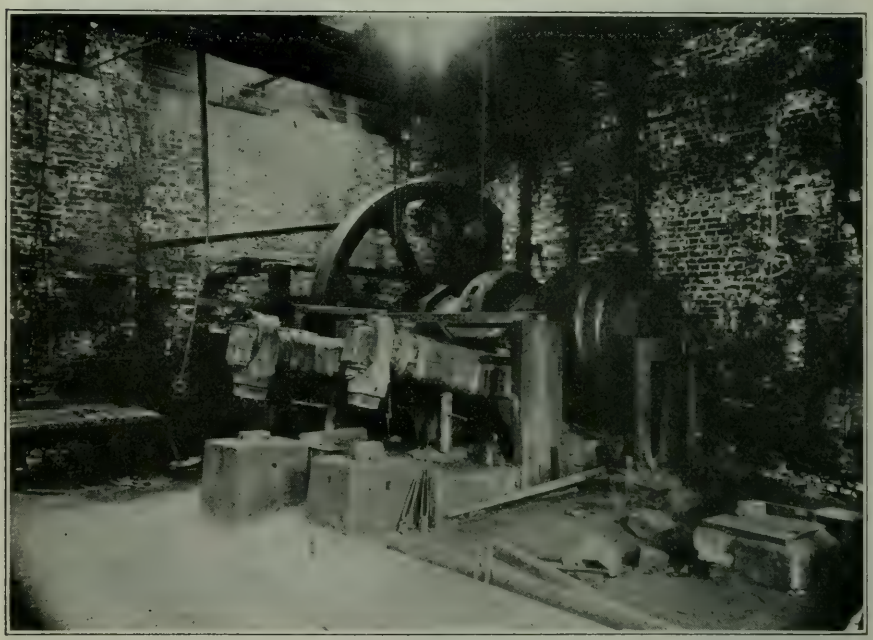


Fig. 4—Eighteenth century water-wheel "tail hammer" still in existence at the works of Peter Stubs, Ltd., near Sheffield, England.

and then day by day moved to a warmer position in the furnace, the drying process altogether taking about 21 days. Excellent pots are produced in this manner, one man and a boy being capable of making 65 to 75 pots per day

and each pot capable of melting three rounds of steel per day. Owing to the fact that the clay pots are extremely fragile when cold, they are made in close proximity to the furnace. As a result of this it is not at all uncommon to find one pot maker working for one concern Monday and Tuesday, for another Wednesday and Thursday, and so on. Fig. 10 shows a core box and charger as used in England. These are two extremely important articles. As will be seen from the cross section of a Sheffield coke-fired furnace shown in Fig. 11, this type of furnace is controlled entirely by the "flues" and the height of the stack. It has natural draught only and yet it is remarkable to what extent the heat can be controlled. A furnace crew consists of:

Fig. 5—A stock of 2000 tons of finest Swedish bar iron.

1 Melter or teemer
2 Puller-outs
2 Cokers
1 Odd man
1 Cellar boy.

The life of the English crucible hole is pretty steady at four weeks. If high carbon steels only are being melted, five weeks could be gotten out of them, but generally speaking, they are knocked and relined every fourth Monday. The relining takes one day, known as "building day," and is usually paid for as a full melting day's work.

At six o'clock every morning work commences with the cleaning out or "slagging" of the walls of the hole. The firebars are then placed in position, a half firebrick or stand placed in the position that the crucibles will ultimately occupy, and a shovel full of fire thrown into the bottom of the hole, thus burying the stand. When the whole 12 holes have been thus treated, the stands or half-firebricks are made bare with a scraper, the clay crucibles withdrawn from an annealing furnace at a dull red heat, and

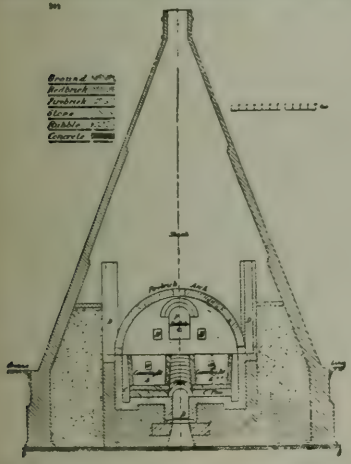


Fig. 6—Sectional diagram of the interior of a cementation, or converting furnace.

Fig. 7—Exterior of a cementation, or converting furnace.

placed upon these stands, care being taken that they are set perfectly straight. Coke is then packed around the pots, up to the lid, the cover placed upon the furnace and it is allowed to burn up. When the furnace has reached a nice heat, and it is essential that this heat be uniform throughout the pot, a handful or so of ordinary sand is thrown into the pot (which has a hole in the bottom). Coke is again added and the heat brought up to a temperature capable of melting the sand, thus cementing the clay crucible to the fireclay half-brick or stand. By this means a reinforced bottom is obtained, and the pot has accepted its own working level for the first heat.

As soon as the sand has fritted or cemented the crucible to the firebrick base, the puller-out turns off the pot lids, the charger or funnel is placed over the pot and the mix added. The lid is then replaced and the melting commenced in earnest.

Coke is added up to the fluc line and gradually burns down. When fairly well burned down the puller-out goes over each hole knocking down any larger pieces of coke that may be adhering to the pot or that may be jammed between the crucible and the walls of the furnace. A second addition of coke, or fire, as it is termed, is made and the furnace allowed to travel. During this heat, the metal in the crucible will become first plastic, or be part molten and part pasty (it is at this period that a second steeling is made, where the whole of the mix would not go into the pot at one charge). A third fire or addition of coke is now made and in the ordinary run of things, when this is burned down the metal will be quite molten. This by no means infers that it is ready for teeming. Were it teemed at this juncture the material, containing, as it does, occluded gases, would be full of blow holes, it would boil over the mold on pouring and be quite spongy. At this and subsequent periods of the melt, considerable difference of opinion sets in as to the best method. The old method adopted for the removal of these gases was to keep the metal molten for various periods of time, with mild steel say, from one hour to one and a half; with harder steels, such as file steels, say, 45 minutes. This was left to the discretion of the melter, who was best able to judge the condition of the furnace, etc.

Later came the use of aluminum, manganese, silicon, titanium, vanadium, and the various less well known alloys, and as the introduction of these assisted to remove the gases in the steel, the time of the melt was reduced and there was, of course, a consequent saving of coke.

Personal experience in Sheffield has taught that the majority of firms use a combination of time, aluminum, and manganese.

The addition of approximately three ounces of manganese (80 per cent ferromanganese) and a killing fire lasting about 45 minutes, will deoxidize or remove the most obstinate gases. Therefore, this practice is pretty well standard. Some firms have their own particular fads and fancies. Titanium has been found useful; vanadium has, of course, other uses besides that of deoxidizing and to use it solely for this purpose would be very expensive.

Aluminum is the most powerful deoxidizer in general use, and one-eighth of an ounce will be sufficient to use with 100 pounds of liquid steel. Sometimes this is added with the ferromanganese before the last or killing fire goes on, but more often a small pellet of about this weight is thrown into the crucible after the flux or scum has been removed and the metal is ready for teeming. Occasionally I have known melters to add aluminum in the mold but this practice is not any too desirable.

When the melter has approved the last pot as sufficiently dead-melted to

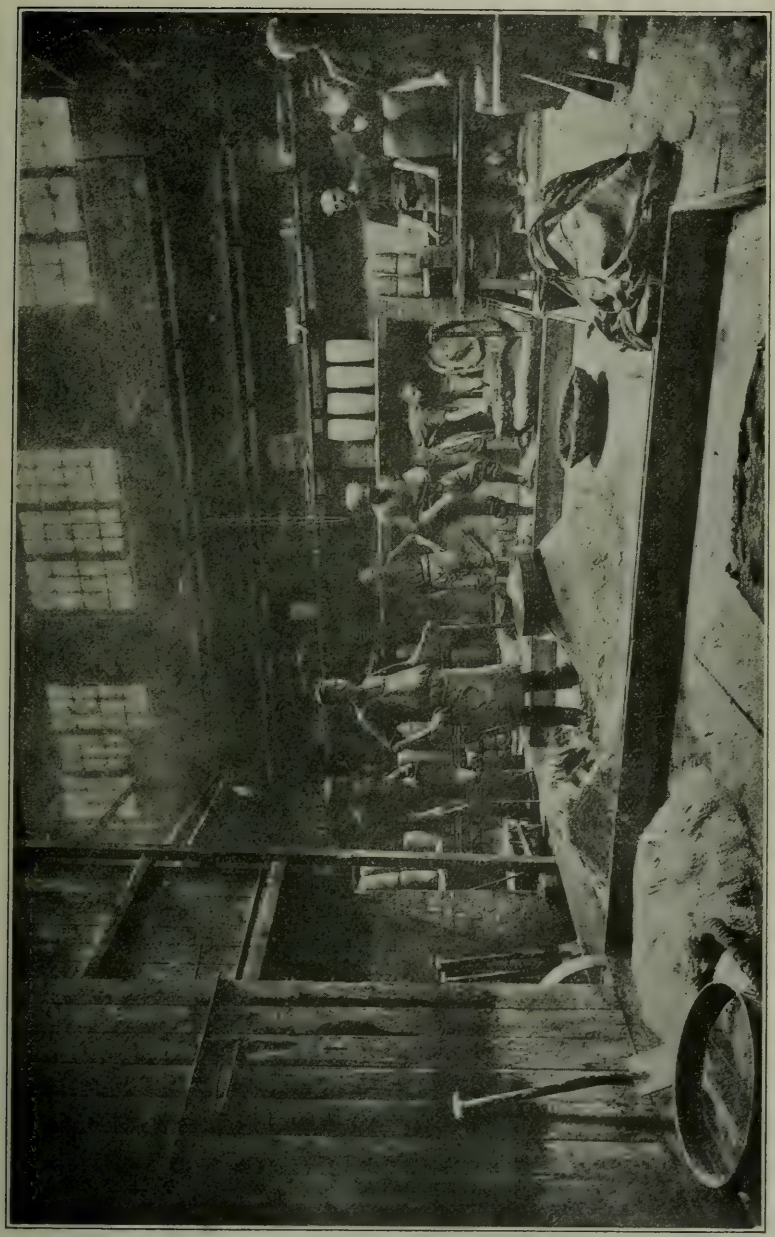


Fig. 8—This illustrates the method of making clay crucibles in Sheffield.

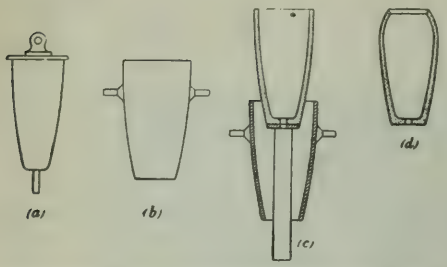


Fig. 9—Plug and flask for molding crucibles by hand. *a*—plug; *b*—flask; *c*—method of stripping crucible from flask; *d*—finished crucible.

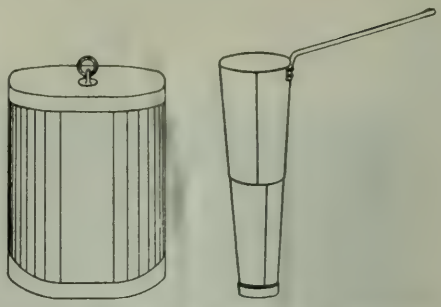


Fig. 10—The core box and charger as used in England are extremely important articles.

withdraw, the puller-outs commence to withdraw their pots, as far as possible, in the order in which they melted, i.e. if there was a pot slow in melting it would be left until the last as from start to finish in teeming a 12-hole crucible furnace, at least 20 minutes will elapse, so that often this interval will allow a doubtful pot to come up satisfactorily.

The second and third heat of the day's work are, in principle, exactly similar to the first, except that the furnace is already hot, the same pots are set back immediately after the teemer has emptied them and while still hot, (for they are as brittle as glass when cold) coke is added up to the level of the lid, so that when the teemer has finished pouring his last pot, the first one he teemed is ready to take the second charge of material and so the day's work proceeds.

As the ingot is teemed, a hot top or dozzle, as it is called in Sheffield, is placed at the top. This, being made of a refractory material, maintains the heat of the metal therein, which in turn feeds down into the shrinkage cavity or pipe which forms on cooling cold, according to the class of steel being made, the dozzle knocked off, as illustrated in Fig. 14. Surface defects are chipped or ground out, and the first part of the manufacture of crucible steel has been accomplished.

A Sheffield coke-hole crucible furnace works only in the day time. Prior to the war a day's work consisted of three rounds of "heats" of carbon steel and thus the furnace is allowed to cool down over night. That is, undoubtedly, a wicked waste of both time and heat, but it always has been, and, probably will continue to be as long as the coke hole

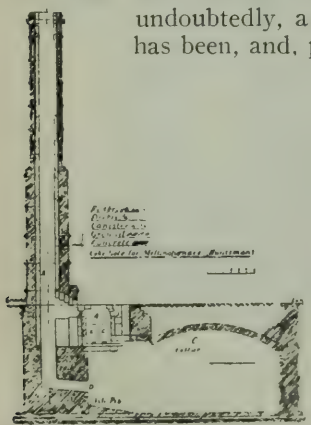


Fig. 11—Section through a Sheffield coke-fired furnace.

Fig. 12—Interior view of a large crucible steel 100-hole melting furnace at Norfolk Works, 163 feet long by 70 feet wide.

remains in use. Continuous running would of course slag up the holes, but it is certain these minor difficulties could be overcome. Nothing, however, has been seriously attempted in this direction and so they continue to work by day and sleep by night as the Lord originally arranged. The output of a coke-hole furnace, running three rounds, would be approximately 4560 pounds. Running, as now, for two heats only 3210 pounds. An American 30-pot gas furnace, running six heats in 24 hours, would produce 18,000 pounds. In Sheffield, the ingot is now passed on, in nine cases out of ten, to the forge. In America, where tonnage and production seem to come first, blooming mills appear to have the preference.

Fig. 13—Teeming in a Sheffield coke-fired furnace.

There is a great deal of argument, as to whether rolled steel is or is not as good as hammered. The writer will content himself with saying that for the most part the people advocating rolled steel invariably have no forge and likewise those advocating hammered stock, invariably are the better fitted to execute orders in that way. The writer's own opinion is that undoubtedly hammered tool steel bars are preferable every time. But by hammered bars, we do not mean bars as obtained here in many plants, where the bars are rolled to within a very slight margin of their finished size and then just hammered sufficiently to leave the impression of the die and so deceive the customer. This trick is not unknown in England, but the customer is pretty near as wise over there as the manufacturer and it would be difficult to get away with. To those buyers, if there may be any here, we would say that unless you know your material is hammered, keep the additional cost in your own pocket, for we can assure you that a bar just planished up as suggested is no better than a bar rolled outright.

The cogging, and ultimate hammering or rolling, is given great care and attention, overheating is strictly guarded against, while decarbonized tool steel forms a very small percentage of the Sheffield output.

The annealing and final inspection and shipment of the material does not differ from the general practice here. The Brinnell hardness test is in general use and is regarded as a simple, reliable, and efficient test for detecting any lack of uniformity in the condition of any batch of material. Time will not permit of dwelling further upon English methods therefore, we will outline the detail method in general use in this country, from which you will see many striking differences. Despite the fact that

Fig. 14—Topping and grading in Sheffield.

the writer is an Englishman he must admit that the production of crucible steel in this country is carried out upon a considerably more elaborate and scientific plan. Certain natural resources which are readily found in England do not exist here, but science and engineering together have done their utmost to overcome this natural handicap.

The American method of production differs in three great essentials from the English. As previously mentioned, in this country the gas-fired furnace is in general use. The three differences are:

1 Source of heat;
2 The furnace itself;
3 The crucible pot.

Compare in your mind's eye the simple coke-hole furnace previously referred to with the elaborate, though highly efficient furnaces illustrated in Figs. 17 and 18.

The source of heat of the design of furnace in use in the works of the plant with which the writer is connected, is the gas producer. There is a difference of opinion even on the arrangement in this country of the gas producer to the furnace, some concerns preferring the producer to be in direct working with its own furnace, whereas others favor a battery of gas

Fig. 15—Small Hammer for Crucible Steel Forging and Tilting.

producers supplying one large main and thence diverted to each respective furnace.

The main claim advanced for direct connection is that the producer can work entirely with the furnace and that the maximum heat can be given at exactly the time required. On the other hand, the chief claim in support of the battery producers, supplying one main, is that a supply of gas is always more or less uniform and if the plant is properly designed an ample supply of gas is always available.

This furnace consists of two or more melting pot holes, on each side of which are two regenerators for gas and air. The producer gas and air pass up through their respective chambers on each side, alternating during the melt, and produce a very satisfactory heating effect. As the melting hole across which the flame passes is very narrow, the gas and air combine and burn in the three narrow flues before entering the melting hole. The progress of the flame through the melting hole is also retarded by having the three inlet ports out of line with the three outlet ports on the opposite side of the melting chamber. A very intense heat is obtained in this manner, so much so that the cutting action of the flame upon the sides of the melting hole is

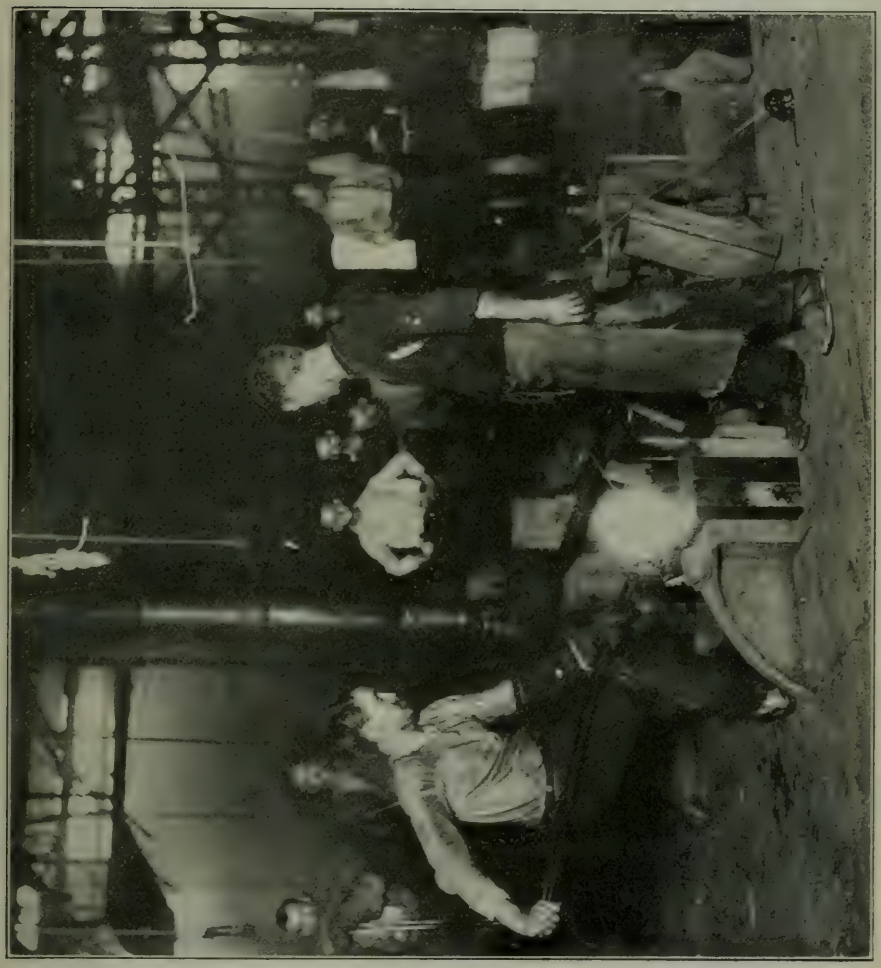


Fig. 16—Typical scene in a crucible steel plant.

most severe, necessitating the use of protecting bricks, which are made of the highest resisting silica fire-brick.

The form of the melting hole (Fig. 19) also encourages the concentration of the heat; the inclination of the brick work on each side of the chamber toward the top deflects the heat upon the crucibles. The crucibles stand on coke dust, which forms the bottom of the melting hole. At the bottom of the coke bed and in the center of the melting chamber, there is a hole which passes right through the brick and iron work forming the bed, to a vault below. This hole is usually covered with an old curcible clay lid, upon which the coke dust rests. Should an accident happen and a charge of steel be lost, a hole is made through the coke bed to the vault bed below, and the steel allowed to fall through. The coke bed is renewed and work proceeds again without much delay.

Fig. 17—Floor view of an American crucible steel furnace plant.

As a rule, two shifts are employed in working this furnace each gang obtaining three heats during the shift; the second gang relieves the first after the third heat is completed, at whatever hour that may be. The furnace works continuously from Monday morning till Saturday morning, when it is patched or repaired if necessary. A hole through the coke bed in the melting chamber is usually made every Saturday, and any clinker and steel from the furnace is pushed through the bottom, after which a fresh bed of coke dust is made.

Each melting chamber holds six crucibles, and is closed by three covers lined with firebrick. As each cover serves for two crucibles, it is unnecessary to move more than one at a time, when placing or removing the crucibles. The regulation of the gas and air is most important for producing uniform heating, which is sometimes very difficult to obtain throughout the melting hole without careful manipulation of the gas and air valves.

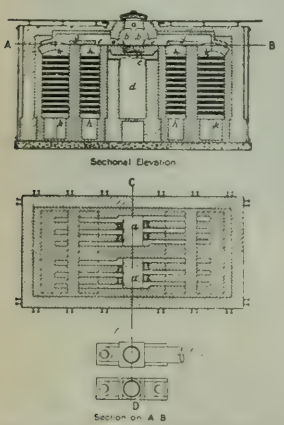


Fig. 18—Sectional view of a crucible steel furnace of an American manufacturer.

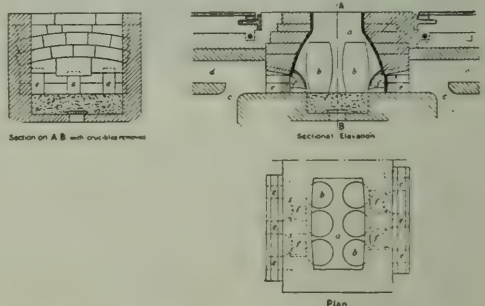


Fig. 19—Sectional diagram of a melting hole.

In America the method of introducing the material into the pots differs entirely from that operation in Sheffield. Here the plumbago pot is, with some firms, charged cold. In other cases they are filled hot and set back, it being claimed more heats are obtained in this way. The weight of the charge varies from 90 to 110 pounds.

The gas-fired furnace is much shallower than the coke-hole furnace, the depth being approximately 33 to 34 inches from the coke bed to the floor level, whereas, in the coke-hole furnace the depth from the fire bars to the floor level varies from 42 to 44 inches. This difference in depth is largely responsible for the fact that it is possible to melt 100 pound weights in America as against 70 pound weights in England.

The American puller-out is able to bring his pot onto the floor with a single lift, (Fig. 20) whereas in England, owing to the increased depth of the furnace, a double lift is necessary. The temperature of the American gas-fired furnace is controlled by gas and air valves, which method offers a striking contrast to the putting on of another basket-full of coke or the

Fig. 20—Drawing a heat.

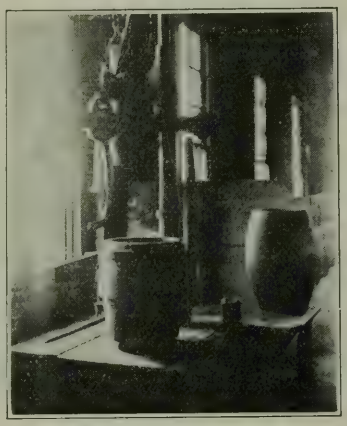


Fig. 21—Manufacturing plumbago crucibles in the plant of an American crucible maker.

closing up of a flue with a fire brick, the only means in Sheffield practice of controlling the temperature. The life of the American furnace varies considerably according to the class of steel that is being melted. If a large percentage of high-speed steel or alloy steel is made, where correspondingly high temperatures are in general use, then naturally the life of the furnace is not nearly as long as it would be were the main product straight high carbon steel. It is quite safe to say that six months would be considered a very poor run while 12 months would be considered exceptionally good. As has been previously stated, the output of an American 30-pot gas-fired furnace would be for six heats, approximately 18,000 pounds in 24 hours.

The crucible pot is made of a different material entirely. In this country the plumbago or graphite pot is in general use. The analysis of this type of pot consisting of a mixture of Ceylon graphite and fire-clay would be somewhat as follows:

	Per Cent		Per Cent
Carbon	50	Alumina	11
Silica	35	Iron Oxide	4

In contrast with the English method, the manufacture of plumbago crucible pots in this country is an industry by itself. Through the courtesy of a Philadelphia crucible company, the writer is enabled to illustrate the final operation in the manufacture of the plumbago crucibles (Fig. 21). The mixture of fire-clays and graphite is scientifically carried out in a series of pug-mills and mixers and the necessary amount of the mixture or ball, as it is termed, is finally spun to shape in the mold.

A homogeneous mixture and a crucible pot with walls that are uniform is thus obtained. The annealing is carried out in bulk and as the plumbago pot is fairly tough and capable of transportation, the American steel manufacturer is able to purchase his crucible pots by the carload, ready for use. Contrast this with the English method of making clay pots which are so fragile that it is impossible to transport them, and their method of annealing over night is just sufficient for the next day's run. It is possible to obtain anything from five to ten heats with a plumbago pot, melting steel, but an average of seven would be considered quite good, which compared with the limit of three in England again draws attention to a comparison distinctly in favor of the American method of production.

Up to this point everything seems to be in favor of this country's methods. But it is at this point that one of the serious difficulties arises. This type of pot, offering as it does such an increased life, has its disadvantages. It is a mixture, as was said before, of refractory clays and graphite, of more or less pure carbon. This carbon is absorbed by the steel in its liquid condition and unfortunately it is not possible to say with any degree of certainty to what extent the carbon absorption will take place. With the English clay pot the degree of uniformity in the finished steel is really remarkable. The writer has personally taken 24 single ingots teemed from clay pots and found no greater variation in carbon content than 0.06 per cent. On the other hand 30 pots from American plumbago pot furnaces showed them to carry in carbon content as much as 0.30 per cent. This, as you will readily appreciate, is a very vital point, and American manufacturers realizing this, in a typical American way, set out to obviate this serious lack of uniformity.

Ladle teeming was introduced. The pots, instead of being teemed direct, are now invariably dumped into a ladle. Sometimes the entire 30 pots will be put into the ladle at once; in other cases, according to the discretion of the manufacturer, a 30-pot furnace will be split into two small ladles. Thus, by the introduction of ladle teeming, a degree of uniformity is established as close as that to which the English manufacturer can work. But, where direct teeming from the pot has to be used, undoubtedly the Englishman is able to work to a closer specification than the American. Ladle teeming is being split into two distinct methods. The one in most general use is known as bottom teeming and is illustrated in Fig. 22.

It is claimed for this process that the possibilities of slag inclusion are extremely remote. It should, however, be borne in mind the stream is controlled by the weight of metal behind it and it is not at all unusual to find the first few ingots cast by this method have very dirty surfaces due to splash. The other method, which is known as top or lip teeming (Fig. 23) although not in general use, the writer is of the opinion that much more satisfactory results are obtained. There are very few types in use, one or two in Germany, a few in Sheffield, England, and a few in this country. It is regretted that it is not possible to go into greater detail on this matter, but it will be seen that this method approaching so closely, as it does, to the hand teem-

ing operation, and obviating, as it does, the effect that a varying weight of metal behind the stream would have, it has every chance of giving results more closely similar to hand teeming than the bottom casting method. The ingot after casting is treated very similarly in this country, with the exception that a considerably larger percentage of material is rolled and in many cases never sees a forge or steam hammer at all.

To touch upon the most vital point in connection with the manufacture of crucible steel, we will refer to the class of material from which it is made. This is essentially the keynote of success or failure, or the production of good or bad steel, as much in one country as it is in the other. The writer can think of no phrase that boils the matter down so well as one used by Prof. Arnold of Sheffield University, who taught me in my younger days, and this phrase was: *If you put the devil in a crucible pot you will get the devil out.* If you give this phrase a second thought, you will see that it means a great deal.

Huntsman started with breaking up pure Swedish iron bars which had been converted in the presence of charcoal to the desired carbon content and remelted the mass in the crucible. No doubt, in the course of time Huntsman himself accumulated a supply of scrap and wondered what to do with it. Unfortunately we have no records to show whether he sold it to the junk man, or whether he introduced some small portions of it into his later steels. It is, however, an acknowledged fact in England that the higher a proportion of Swedish iron a mix contains, the better the quality of the ultimate steel. Desire for increased profits, keen competition, and other causes, have at one time or another prompted steel manufacturers in both countries to dilute their steel mixes. This can undoubtedly be carried too far. David Carnegie in his excellent book on *Liquid Steel* gives a few typical mixes. For high-speed steels he recommends Swedish iron entirely, with the necessary additions of tungsten, chrome, vanadium, etc. For ordinary carbon steel, he gives examples containing as much as 60 per cent Swedish iron, diluted with 40 per cent carbon steel scrap.

Fig. 22—Bottom teeming. Pouring the ingots.

Few writers and fewer steel manufacturers seem inclined either in their books or papers to give much information of mixes. It may, therefore, be of interest if a few hints on general practice in this direction are given. Such mixes as are mentioned, of course, are not the mixes of any one firm with whom the writer has been employed, for such would not be fair, but it will give you an idea how prices affect quality.

High-Grade Quality	
80 per cent Swedish Iron	Sometimes split in ratio 60 per cent Swedish and 20 per cent domestic.
20 per cent Carbon steel scrap	Usually of the same mix
Second Quality	
60 per cent Swedish iron	Split, say 40 per cent Swedish and
40 per cent Carbon steel scrap	20 per cent domestic.
Third Quality	
50 per cent Swedish iron	Split, say 30 per cent Swedish and
50 per cent Carbon steel scrap	20 per cent domestic.

Speaking of steel manufacturers in general, very few could obtain the price it would be necessary to ask for a quality higher than No. 1, and on the other hand, there is perhaps no reputable steel maker who would care to make crucible steel of a cheaper quality than No. 3.

The question of Swedish iron is a very broad one. In Sheffield, each particular firm jealously guards the brand of iron it uses. The writer's late employers had the exclusive use in England of "Big S," but as no more of this is now made, he is betraying no secret. Other irons in regular use are:

"W & Brown"	"L. T. S."	"J. M."
"Hoop L"	"L. G."	"B. F. S." etc.

All of these are good irons. You have here your own domestic irons the makers of which claim strongly that they are quite equal to Swedish.

During the war a great deal of domestic American iron was bought by

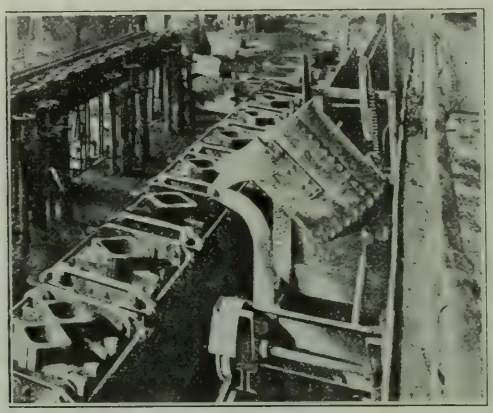


Fig. 23—Lip teeming.

the British Government and used in Sheffield, and our experience did not prove it equal to the Swedish.

As American iron is cheaper than Swedish, some firms over here use it entirely, but the wiser concerns and those with which quality counts, use Swedish or a combination of both.

Recently a metallurgist of a prominent firm in this country stated, when asked his opinion on Swedish and American irons, that the only advantage in Swedish iron was to be able to say you used it for the sake of the advertisement. The writer's opinion, based on 20 years' work with crucible steels, is that nothing equal to Swedish iron, as a base, has yet been found. That is why most of the foremost firms in the United States use it.

There are some people in a small way of business who believe they can put anything into a crucible, from old tires and rails downwards, and still call their product crucible steel, but I have no hesitation in saying that I would certainly prefer a piece of good basic open-hearth steel to a rotten and inferior piece of material even if it had the halo around it of having been melted in a crucible.

We have previously referred to the fact that production does not always coincide with service and quality, and that an attempt to standardize the tool steels of the world has as its primary object the increase and standardization

of production. As the writer is from that very conservative school which still holds the belief that there is a special steel for special purposes and a special steel for special conditions. To standardize steel alone would necessitate more or less the elimination of the human element and throw us entirely dependent upon mechanical or scientific control. Being a metallurgist, the writer realizes this as a beautiful "metallurgical dream," but by way of warning, we must not forget or for a moment lose sight of the fact that the human element and rule of thumb methods controlled the steel industry for many decades past, that the science of metallurgy is still in its infancy, and that day by day we have proof that works practice can cope with difficulties which metallurgical minds cannot altogether explain. Let us, therefore, try to bend our theories to meet proven facts, rather than attempt to bend works practice too much to meet our theories.

Analyses of a few high-grade alloy steels which were manufactured by the writer in England, and used for special purposes may not be out of place.

In England, practically all the leading tool-steel manufacturers produce three qualities of high-speed steel, something similar to the following:

Twist Drill

Carbon	0.50/0.70
Silicon	trace
Manganese	not over 0.20
Sulphur	low as possible
Phosphorus	low as possible
Chromium	2.50/3 per cent
Tungsten	12/14 per cent
Vanadium	Nil to trace

Standard

Carbon	0.55/0.65 per cent
Silicon	trace
Manganese	0.20 per cent
Sulphur	low as possible
Phosphorus	low as possible
Chromium	2.75/3.50 per cent
Tungsten	14/16 per cent
Vanadium	Nil to 0.50 per cent

Super.

Carbon	0.55/0.65 per cent
Silicon	trace
Manganese	0.20 per cent
Sulphur	low as possible
Phosphorus	low as possible
Chromium	3/4 per cent
Tungsten	16/18 per cent and sometimes up to 20 per cent
Vanadium	0.50/1 per cent

Molybdenum is used by some manufacturers in varying proportions from traces up to as high as 3.5 per cent. Of course, it will be remembered that Prof. Arnold recently caused a stir by claiming that a steel containing approximately 6.00 per cent molybdenum, without tungsten, had beaten an ordinary 18.00 per cent tungsten steel. However, 18.00 per cent tungsten steel still holds sway. Molybdenum is, nevertheless, an alloy worthy of special attention and will undoubtedly figure in no small way in the future.

Magnet Steel

	Per Cent
Carbon	0.55/0.65
Silicon	0.20 not over
Manganese	0.20 " "
Sulphur	0.025 " "
Phosphorus	0.025 " "
Tungsten	5.50/6

Purpose:

This steel is particularly suited to the manufacture of magnets for electric meters, magnetos for motor cars, telephone work, and all other purposes where the best steel obtainable is required.

Heat Treatment:

The hardening depends a great deal upon the exact purpose for which this class of steel is used but I have found the following to be most

satisfactory: Heat slowly and uniformly to a temperature in the neighborhood of 825 to 850 degrees Cent. (1510 to 1570 degrees Fahr.) i. e., a full bright red heat, and quench outright in clear cold water. If the article to be hardened is of intricate shape and design, warm water or even oil may be found desirable to quench in.

Special Alloy Steel

	Per Cent
Carbon	1.10/1.20
Silicon	0.20 not over
Manganese	0.20 " "
Sulphur	0.025 " "
Phosphorus	0.25 " "
Chrome	0.75/1
Tungsten	3/3.50
Vanadium	0.25

This steel is specially designed to meet the requirements of the machine shop where ordinary crucible cast steel is not satisfactory, and yet where a high-speed steel is not necessary. It is also a superior quality for roll turners' tools, and in instances where an extremely keen cutting edge is required, capable of withstanding heavy wear.

Heat Treatment:

This is another extremely delicate steel and requires considerable care in the heat treatment: It should be heated slowly and uniformly to a temperature of approximately 800 to 825 degrees Cent. (1480 to 1520 degrees Fahr.) and quenched in clear, cold or tepid water.

Combined Iron and Steel

Cast together—not welded.

		Per Cent
Iron:	Carbon	not over 0.20
	Silicon	not over 0.20
	Manganese	not over 0.20
	Sulphur	not over 0.025
	Phosphorus	not over 0.025
	Nickel	not over 0.25
Steel:	Carbon	0.85/0.90
	Silicon	0.20
	Manganese	0.20
	Sulphur	0.025 (not over)
	Phosphorus	0.025 (not over)
	Nickel	0.25

Stainless Steel

	Per Cent
Carbon	0.25/0.35
Silicon	0.20
Manganese	0.20
Sulphur	0.025
Phosphorus	0.025
Chromium	13/14
Nickel	Trace

This steel is used for cutlery, etc., and anywhere where non-corrosive and unstainable steel is required.

The heat treatment varies. It is generally hardened about 1050 degrees Cent. (1920 degrees Fahr.) and tempered up to 450 degrees Cent. (940 degrees Fahr.), according to requirements.

Wortle Plate or Drawing Die

	Per Cent
Carbon	1.50/2
Silicon	0.20
Manganese	0.20
Sulphur	0.025
Phosphorus	0.025
Chromium	12/12.50

Produced specially for drawing dies, where maximum hardness and abnormal wearing properties are essential.

Heat treatment: Although it is possible to harden this steel with great care in water, it is not generally adopted, satisfactory results being obtained by heating the material carefully and uniformly to a temperature of approximately 850 degrees Cent. (1570 degrees Fahr.) and quench in cold, clean oil.

Alloy Chisel

	Per Cent
Carbon	0.55
Silicon	0.20
Manganese	0.20
Sulphur	0.025
Phosphorus	0.025
Chromium	0.25/0.50
Tungsten	0.75/1

It is used for pneumatic chisels, etc., where a higher priced steel is warranted.

Heat treatment: Harden in oil or water from 775 degrees Cent. (1430 degrees Fahr.) and temper according to requirements.

Alloy Die Steel

	Per Cent
Carbon	0.65/0.70
Silicon	0.20
Manganese	0.20
Sulphur	0.025
Phosphorus	0.025
Chromium	0.25/0.50
Tungsten	0.75/1

This steel is for making dies and general press tool work.

Heat treatment: Harden in oil or water at approximately 775 degrees Cent. (1430 degrees Fahr.).

Hack Saw

	Per Cent
Carbon	1.10/1.20
Silicon	0.20
Manganese	0.20
Sulphur	Low as possible
Phosphorus	Low as possible
Tungsten	1.25/1.50
Chrome	traces/0.25

The heat treatment of this class of material is so generally known here that it is unnecessary to go into detail. Hardening and tempering vary according to the experience of the particular user.

Fig. 24—A series of mixes already weighed up showing in the front of the weigh pans the large percentage of Swedish iron used at the plant with which the author is associated.

The English method of crucible steel production is simple and the natural resources in clays, etc., result in a highly satisfactory and uniform material. The tonnage production is considerably lower, but so also is the cost of labor and particularly the cost of crucibles. A clay crucible costs about 2s 6d, i. e., 60 cents. The usual practice is for the firm to provide all raw materials and buildings to work in and the man then receives about 16 cents per pot, piece work.

Compare this with $5.00 per pot, which is the price of the average American crucible today.

But remember, also, how the output compares.

English 4500 pounds in 3 heats, or 3200 pounds in 2 heats.

American 18,000 pounds in 6 heats.

The introduction of ladle-teeming established a standard of uniformity in

American steels quite comparable with the English and so this difficulty was overcome.

As proof of this the fact that superfine steel can and is being produced in America is borne out by the fact that in Sheffield, England, American made saws are to be found, and assurance can be given Americans that their steel makers are in serious competition in every way with the Sheffield producers. The tremendous varieties of steels used in a saw, file and tool-steel works are proof of this statement.

The writer says without fear of contradiction that if the American manufacturer puts as good material into his crucible as his English or continental competitor, despite the difference in the methods of production, he can obtain quite as good a steel in the *ingot* with a considerably increased tonnage.

Undoubtedly there will be those who will wonder why, if my statement is correct, so much English steel is still imported by this country.

Some will say that in the first place the cause is due to the prejudice of certain toolsmiths, etc., who "swear by" certain brands of Sheffield steel and won't even try any other. Personal prejudice has always been a great influence, and this is, therefore, true in some cases, but there are other reasons.

Without wishing to deprecate the merits of American steels, the writer's candid and frank opinion is, that the chief fault is with the national desire all the time for *increased production, tonnage, tonnage, tonnage.*

This has led, in many cases, to the entire abandonment of hammering and the substituting of rolling. Speeding up of the mills has necessitated the raising of rolling temperatures with its consequent risk of overheating and decarbonization. Great care is taken to avoid decarbonization and overheating in England where the *steel maker* tells the *engineer* what he wants.

Here the production engineer more often tells the steel maker what the mills are geared up to and he has no alternative but to abuse the steel in the endeavor to keep pace.

Many American catalogs contain the advice to remove up to ⅛ inch to get off a decarbonized surface. A film of decarbonization will always exist, but to openly admit decarbonization to such an extent, is nothing short of calamity. "Open confession is good for the soul," but *these are some of the reasons* why some of your best toolsmiths prefer English steels. Results prove the latters' uniformity and its freedom from overheating and decarbonization. You can do it here, if you will. You have solved some of the big problems and placed yourselves as a nation ahead, so far as the mechanical end goes, then why let the metallurgical details spoil your productions? A word or two of advice to any American who puts quality first is to delve into the *metallurgical* details with the same energy and enthusiasm with which he approached the bigger *mechanical* problems.

Finally, let me urge the necessity of dealing only with houses of repute.

Urge upon your buying departments the folly of buying high-grade steels from unreliable sources, for a cent or a fraction of a cent per pound less.

Think how a cent or so difference in cost of a piece of steel may "make or mar" a very expensive finished machine tool.

Take your steel maker more into your confidence in placing specifications, for in many cases he is quite willing and able to help you in the selections of suitable steel.

STEEL IS STEEL

By C. F. Smart

TWO darkies were engaged in a technical discussion:
"Ain't steel an i'on jus the same?"
"Cose not, they diffahs."
"How so?"
"Well, steel has some i'on in it, but i'on is i'on an steel is steel".

This seems to be the idea of many people, and too frequently in plants using steel as a raw material, the necessity of careful classification and segregation based on chemical and metallurgical inspection, is not readily apparent. The writer has had occasion to note some results of using steel where ordinary precautions of handling were maintained, the stock being kept in bins according to size and type, without laboratory inspection as a guide to acceptance and classification. Investigations of this stock and of rejected parts made from it, disclosed numerous instances where stock of entirely wrong composition had crept into production, instances which should convey an important message to the "steel is steel" type of man, whether he be plant official, or ultimate consumer. Among the examples were:

Camshafts that were too hard to machine, were found to have carbon contents varying from 0.30 to 0.50 per cent.

Broken crankshafts, supposedly made from 1045 steel, actually contained 0.15 to 0.25 per cent carbon.

Axles that could not be heat treated successfully showed 0.30 per cent carbon instead of the 0.40 per cent required.

Gears, for which were specified steel of 0.40 to 0.50 per cent carbon and a minimum Brinell hardness of 418 after water quenching, showed hardness values of 241 to 321 instead, and ran but 0.30 per cent carbon.

Gears of the same specification, which cracked into several pieces on quenching, gave analysis of 0.57 to 0.62 per cent carbon, and 1.45 to 1.66 per cent manganese.

Similar gears, showed a Brinell hardness of 126 after quenching, and analyzed 0.07 per cent carbon, 0.39 per cent manganese.

Camshafts rejected because of soft spots after hardening, were found to have been made from steel with up to 0.070 per cent phosphorus content.

A bar to bar analysis of several heats of 1020 stock disclosed seventy bars of 0.30 to 0.45 per cent carbon, which otherwise would have been forged into about 400 camshafts and 600 gears, to be rejected at some point in process as unfit for use.

Such instances are representative of difficulties that may arise in the use of improperly segregated steel; but these are not all for the losses incurred in heat treating mixed stock may easily become serious, with accompanying lowering of production or quality. All of the stock may satisfactorily meet the composition requirements for a given type; but it may be shown that steels of practically identical composition do not necessarily respond in like manner to the same treatment. A typical ex-

A paper presented by title before a meeting of the Society. The author, C. F. Smart, was assistant metallurgist, Ingalls-Shepard Division, Wyman-Gordon Co., Harvey, Ill.

ample of this nature was found in the case of three heats of 1045 steel whose composition ranges as shown by analyses of samples from six bars of each heat were as follows:

Heat	Size	Carbon per cent	Manganese per cent	Phosphorus per cent	Sulphur per cent
A	3 inch round	0.41—0.45	0.54—0.78	0.035—0.042	0.025—0.042
B	3 inch square	0.40—0.44	0.55—0.60	0.020	0.034—0.038
C	2 5-7 inch square	0.42—0.46	0.63—0.69	0.24	0.044—0.048

Sections from bars of each heat were held for two hours at 1525 degrees Fahr., quenched in water, reheated to 1000 degrees Fahr. for two hours and cooled in air. The Brinell hardness values as determined

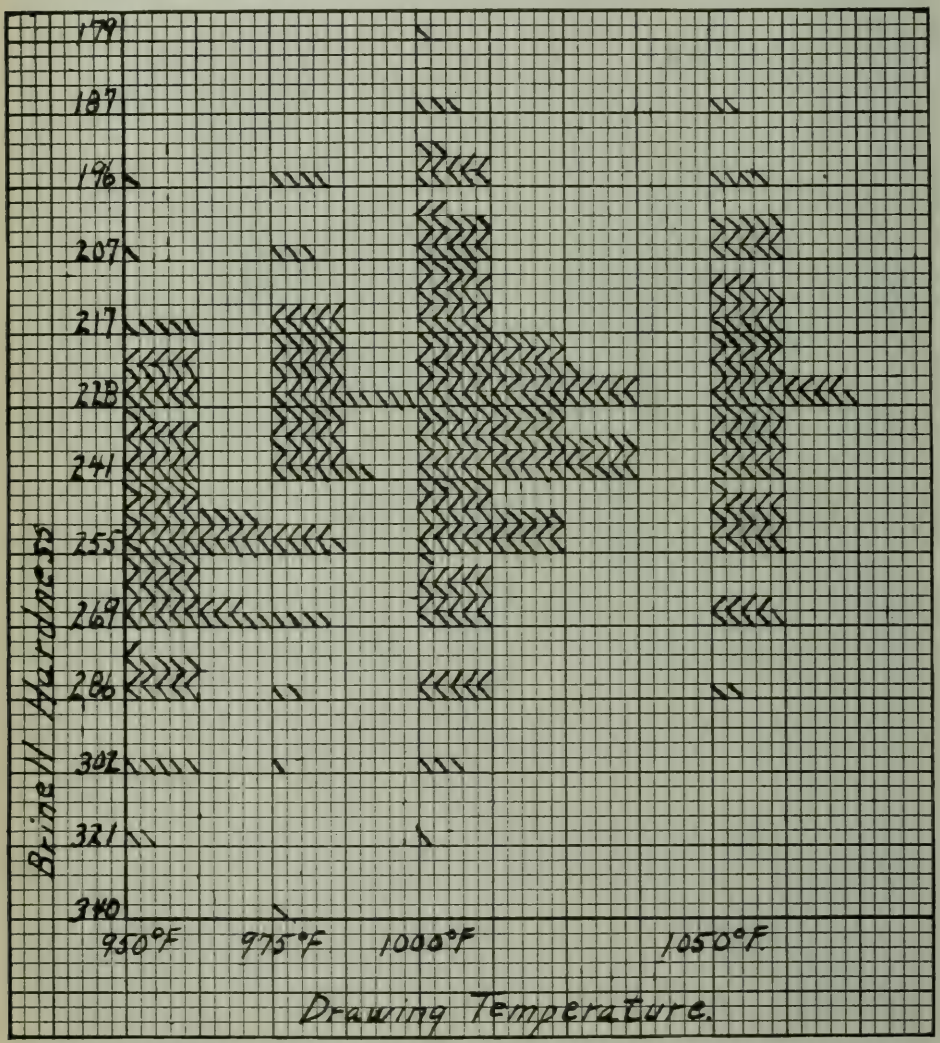


Fig. 1—Brinell hardness-drawing temperature chart. Number of tests falling in each class are indicated by number of diagonal lines appearing in small squares

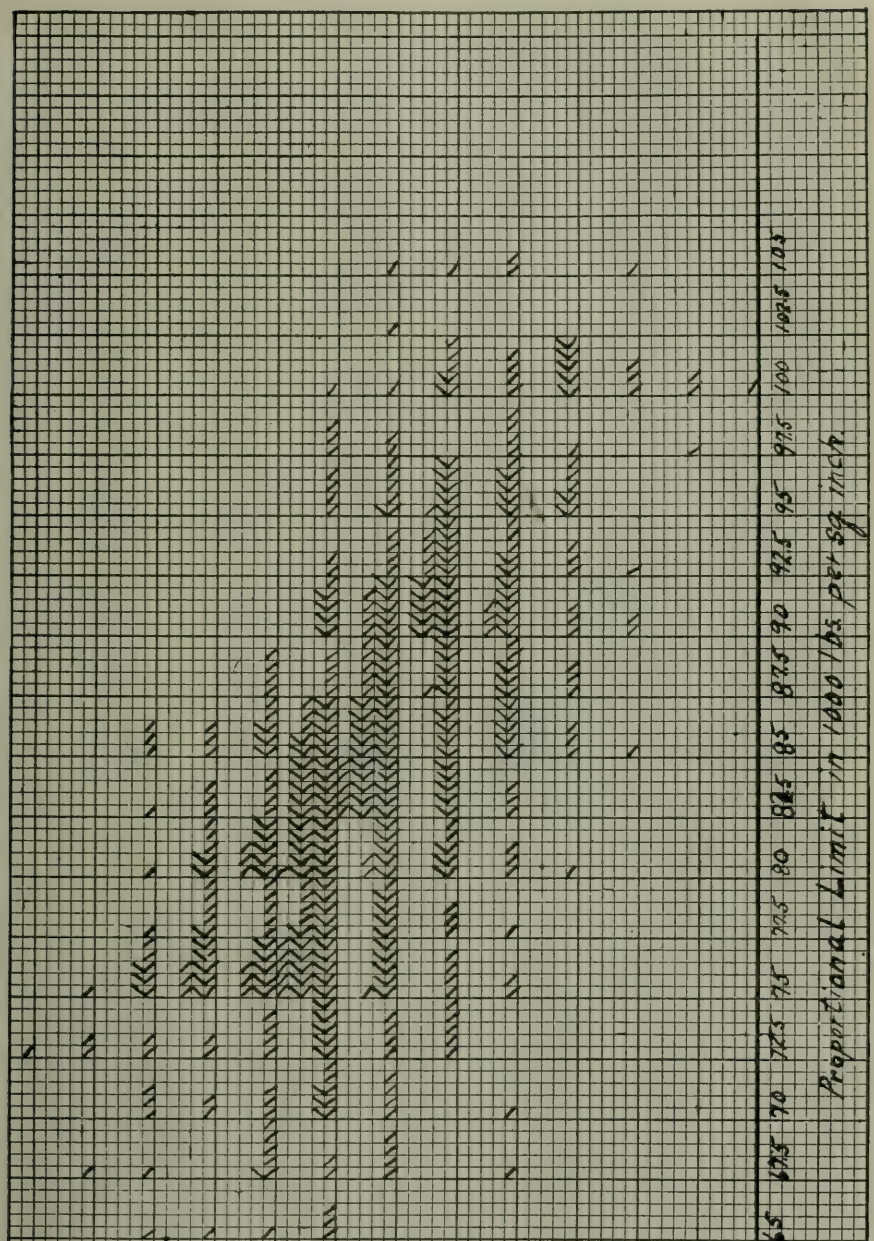


Fig. 2—Brinell hardness-proportional limit chart. Number of tests falling in each class are indicated by number of diagonal lines appearing in small squares

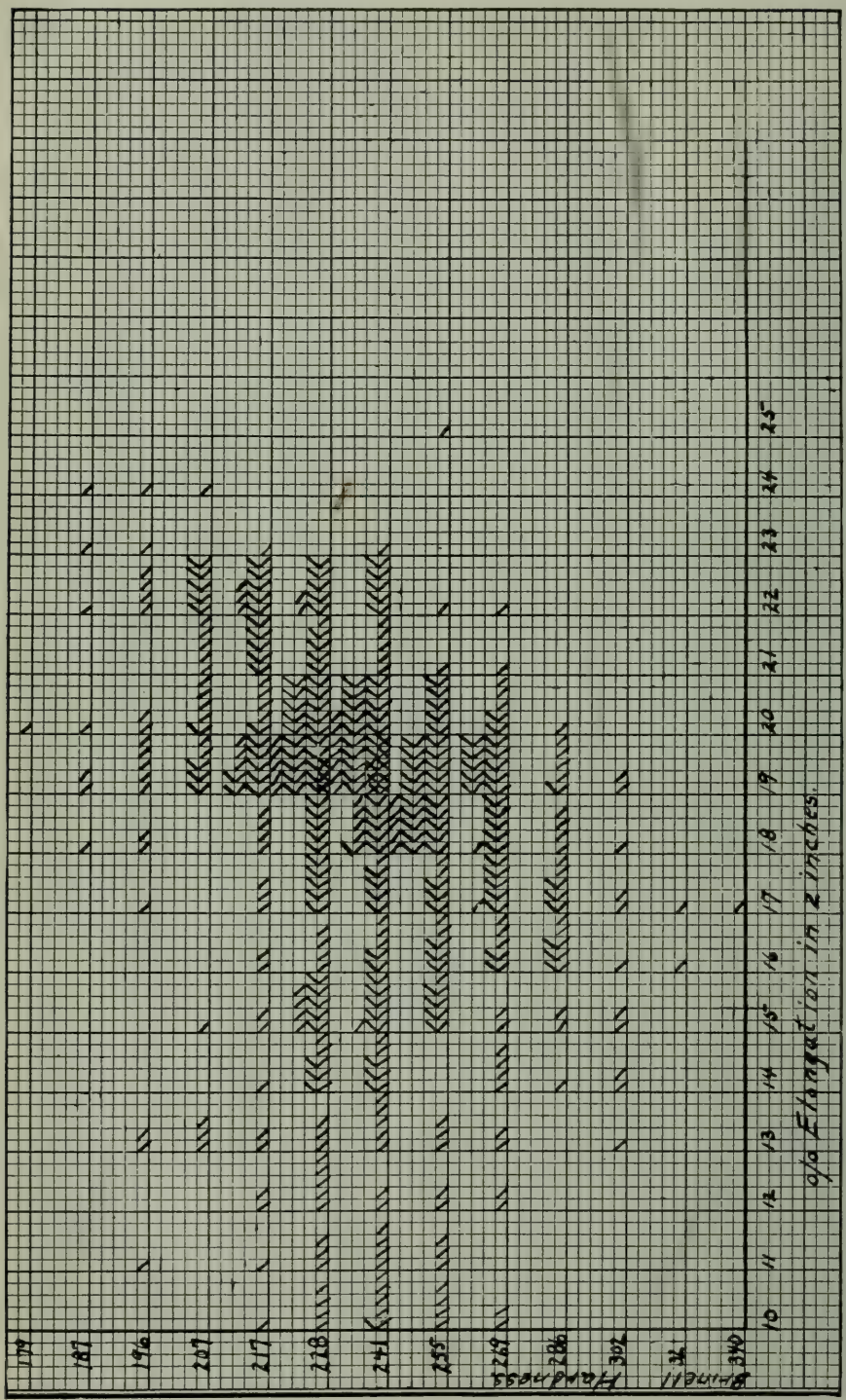


Fig. 3—Brinell hardness—Elongation chart. Number of tests falling in each class are indicated by number of diagonal lines appearing in small squares

TABLE I.

TEMPERATURE—BRINELL DATA

Temperature degrees Fahr.	Number of tests: Class 1	Class 2	Class 3	Class 4	All classes
950	12	13	24	95	144
975	52	..	24	14	90
1000	32	27	69	129	257
1050	7	14	22	86	129
Totals	103	54	139	324	620

Tests Showing Less Than 217 Brinell

Temperature degrees Fahr.	No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent
950	..	....	..	....	1	4.2	2	2.1	3	2.1
975	4	7.7	..	....	7	29.2	..	....	11	12.2
1000	4	12.5	3	11.1	16	23.2	15	11.6	38	14.8
1050	2	28.6	..	....	5	22.8	17	19.8	24	18.5

Tests Showing Over 255 Brinell

950	9	75.0	10	77.0	8	33.3	34	35.8	61	42.4
975	1	1.9	..	....	4	16.6	8	57.0	13	14.3
1000	3	10.0	6	22.2	11	15.9	13	10.1	33	12.8
1050	1	14.3	1	7.2	1	4.5	8	9.3	11	8.5

Tests Showing 217 to 255 Brinell

950	3	25.0	3	23.0	15	62.5	59	62.1	80	55.5
975	47	90.4	..	....	13	54.2	6	43.0	66	73.3
1000	25	78.0	18	66.6	42	60.9	101	78.4	186	72.5
1050	4	57.1	13	92.8	16	72.7	61	71.0	94	72.8

after the quench and draw were:

Heat	Brinell hardness after quench	Brinell hardness after draw
A	555—600	262—286
B	340—444	241—269
C	286—340	217—241

In heat treating crankshafts forged from these heats it was necessary to draw *A* at 1050 degrees Fahr., *B* at 1000 degrees Fahr. and *C* at 875 degrees Fahr., in order to meet the same hardness requirement of 217 to 255 Brinell.

The response to heat treatment of nine heats of hot-rolled, 3-inch square, 1045 steel, was followed metallographically. In condition as received, examined at 100 diameters magnification the grain size varied in appearance from four or five grains to the linear inch in the most refined heat, to grains an inch to 1½ inches diameter in the least refined heat. Full size sections were given a normalizing treatment, holding at a temperature of 1600 degrees Fahr. for three hour periods and sections examined after three hours, six hours and nine hours at heat. The steel with the finest initial grain was very well refined after three hours while the stock with the coarsest initial grain showed no indication of refinement after three hours, was partially refined after six hours and still not completely refined after nine hours treatment. Could uniform physical properties be expected following an ordinary quench and draw of a mixed lot of forgings from these heats?

A summary of over 600 tensile tests made on coupons forged from 1045 steel shows quite clearly some of the variation that may be encountered in heat treating mixed heats of the same type of steel. These coupons were forged to a section 2½ inches in diameter from bars varying in size up to 4 inches diameter. After forging they were heat treated under laboratory conditions in electric muffle furnaces subject to accurate pyrometer control. The tensile test specimens were taken midway be-

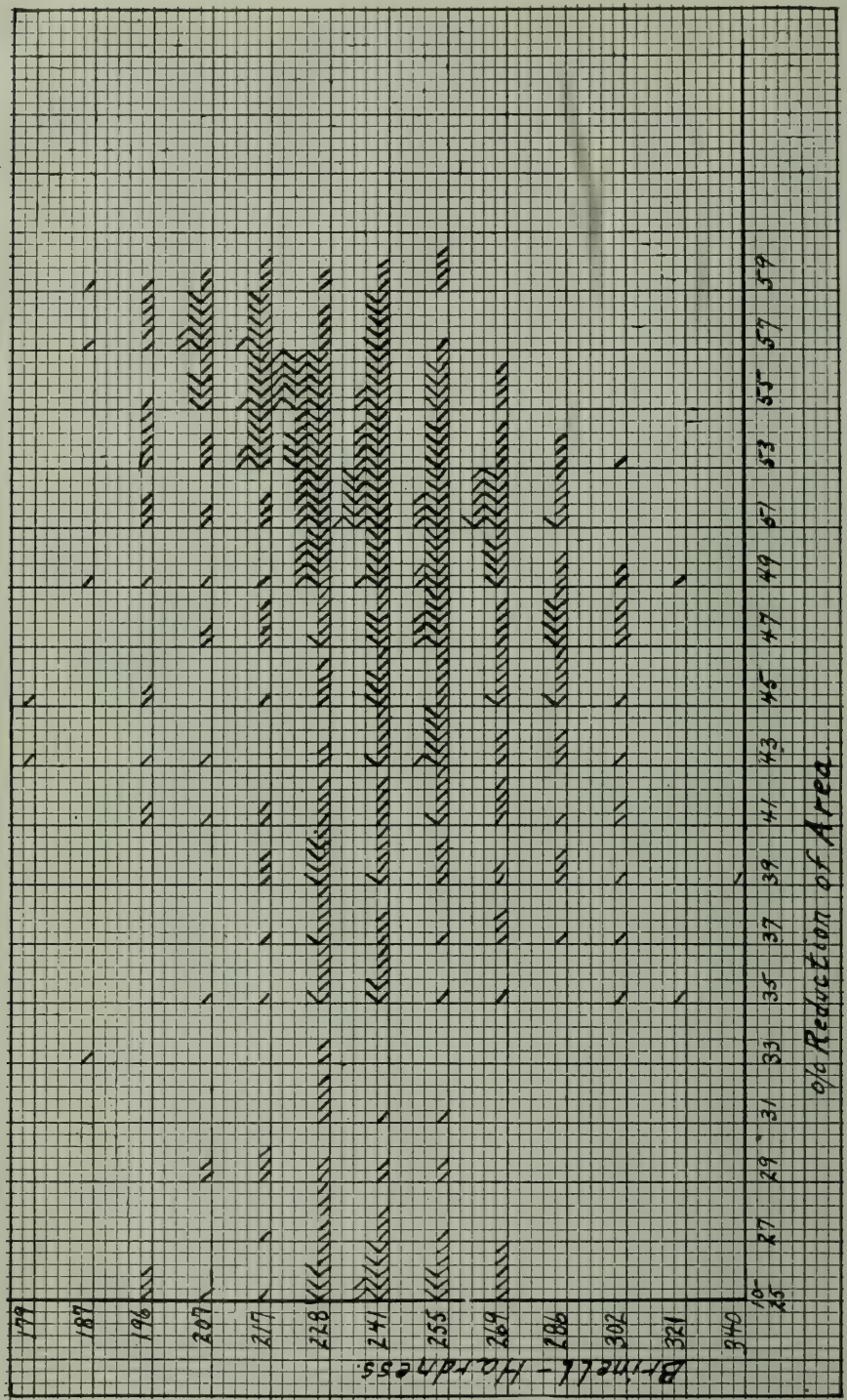


Fig. 4—Brinell hardness—Reduction of area chart. Number of tests falling in each class are indicated by number of diagonal lines appearing in small squares

tween center and surface of the coupons. Heat treatment consisted in a water quench from a temperature of 1525 degrees Fahr. and a draw at temperatures of 950, 975, 1000 and 1050 degrees Fahr.

The steels upon which these tests were made were all within the S. A. E. specification for 1045 steel: Carbon 0.40 to 0.50 per cent, manganese 0.50 to 0.80 per cent, phosphorus 0.045 per cent maximum and sulphur 0.050 per cent maximum. For the purpose of this summary they were divided into four classes as follows:

	Carbon percent	Manganese per cent
Class 1	0.40—0.45	Less than 0.60
" 2	0.45—0.50	" " "
" 3	0.40—0.45	Over " "
" 4	0.45—0.50	" " "

Division of the above was made in accordance with results of analyses of at least six bars of each heat. Lots with a composition range too wide for any single group were omitted from consideration. As so classified there were 17 heats in Class 7, 9 heats in Class 2, 24 heats in Class 3, and 55 heats in Class 4. Results have been tabulated by classes,

TABLE II.

BRINELL, PROPORTIONAL LIMIT, REDUCTION OF AREA AND ELONGATION DATA

	Class 1		Class 2		Class 3		Class 4		All classes	
	No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent
Tests under 217 Brinell..	10	....	3	....	29	....	34	....	76	....
OK for proportional limit	8	80.0	..	....	22	76.0	32	94.0	62	81.5
OK for reduction of area	7	70.0	2	66.6	21	72.5	34	100	64	84.1
OK for elongation.....	9	90.0	1	33.3	25	86.2	31	91.2	66	86.8
Tests 217-255 Brinell....	79	....	34	....	86	....	227	....	426	....
OK for proportional limit	65	82.4	33	97.0	86	100	227	100	411	96.5
OK for reduction of area	34	43.0	15	43.1	60	69.8	172	75.7	281	66.0
OK for elongation.....	49	62.0	32	94.0	74	86.0	200	88.0	355	83.3
Tests over 255 Brinell..	14	....	17	....	24	....	63	....	118	....
OK for proportional limit	14	100	17	100	21	87.5	63	100	115	97.5
OK for reduction of area	9	64.3	12	70.5	18	75.0	40	63.5	79	67.0
OK for elongation.....	12	85.8	16	94.1	20	83.3	61	97.0	109	92.5
Total number of tests....	103	....	54	....	139	....	324	....	620	....
OK for proportional limit	87	84.4	50	92.5	129	92.8	322	99.3	588	94.8
OK for reduction of area	50	48.5	29	53.8	99	71.2	246	76.0	424	68.4
OK for elongation.....	70	68.0	49	91.0	119	85.6	292	90.0	530	85.5
OK for Brinell.....	79	76.6	34	63.0	86	61.8	227	70.0	426	68.8

with drawing temperature, proportional limit, per cent elongation in 2 inches, and per cent reduction of area referred to Brinell hardness value, bearing in mind the specification for physical properties that the treated stock was required to meet, that is proportional limit 70,000 pounds per square inch, elongation in 2 inches 15 per cent minimum, reduction of area 45 per cent minimum, and Brinell hardness 217 to 255. Summaries of such tabulation are presented in Tables I and II.

The percentages calculated for Table I represent the ratio of the number of tests of one class drawn at a specified temperature and showing the given Brinell range, to the total number of tests of this class and draw temperature. The percentages of Table II represent the ratio of those tests of tensile property above the specified minimum, to the total in each class and Brinell range.

Examination of these tables gives some idea of the difficulty of obtaining a product of uniform properties in heat treating a mixture of stock of this nature. For 1045 steel as a type, the best practice obtained for any one drawing temperature was 73.3 per cent, based on the Brinell test, while for all temperatures the average practice was 68.8 per cent.

Figs. 1, 2, 3 and 4 have been plotted to show graphically the distribution of results as obtained on all classes combined. The Brinell value has been plotted against the values for temperature of draw, proportional limit, per cent elongation and per cent reduction of area. A section of the paper between two Brinell values and two values for the other property under consideration was taken as belonging to tests showing the values toward the left and bottom of the diagram. A mark has been made through one small square to represent each test. In plotting it was necessary to use wider ranges between units than those to which the actual readings were taken and for this reason there may be slight discrepancy between the numerical and the graphical data. It is believed, however, that this has in no way affected the value of the diagrams and that they are true pictures of the distribution of the values obtained. These figures show for 1045 steel:

That when quenched from a proper temperature and drawn at any of the temperatures used for these tests, the Brinell values may be distributed over a very wide range.

That for a specified minimum Brinell hardness of 217, more than 10 per cent of the values for proportional limit were below the specified minimum of 70,000 pounds per square inch.

That for a given Brinell hardness value, the values for proportional limit may vary widely. Thus at 228 Brinell, 90 per cent of the values for proportional limit are quite uniformly spread over a range of from 70,000 pounds per square inch to 90,000 pounds per square inch.

That the Brinell value cannot be accepted as definite assurance of what the values for elongation and reduction of area will be. At 228 Brinell, 17 per cent of the values for elongation are below the specified minimum of 15 per cent, at the same hardness value 35 per cent of the figures for reduction of area are below the specified minimum of 45 per cent.

That it would be impossible, treating this mixed stock, to turn out a highly uniform product from the heat treating plant, and at the same time to maintain a low percentage of rejection.

It is not within the scope of this paper to discuss the causes of such variation. It may be argued that good steel, properly forged, would show better results than these. Granting this point, how is the heat treater to distinguish the good steel from the bad, the well worked piece from the poorly worked? Can better practice and greater uniformity be maintained, if the heat treating force is required to accept mixed heats of a given type and left to guess at an average treatment?

A study of the tabulation of several hundred thousands of hardness determinations on heat treated stock leads to the belief that about 70 per cent practice is all that can be consistently obtained in the commercial treatment of carbon steel forgings from mixed heats, working to a Brinell range of 0.3 millimeters. The same is true for certain so-styled individual heats, in more than one of which a variation of carbon content of from 0.38 to 0.51 per cent has been found. On the other hand if steel be kept properly segregated according to individual heats, which have been checked with a sufficient number of analyses to assure uniformity, it is entirely possible by basing heat treatment on results of experiment and metallurgical tests, to maintain a practice of 99 per cent

(*Concluded on Page* 334)

DISCUSSIONS FOLLOWING PAPERS PRESENTED AT THE TUESDAY MORNING TECHNICAL SESSION OF THE ANNUAL CONVENTION, DETROIT, OCTOBER, 1922

THE first technical session held during the annual convention of the society in Detroit, Oct. 2-7 was called to order by the chairman, Prof. H. M. Boylston of Case School of Applied Science, at 10 a. m. Tuesday, Oct. 3.

H. B. Knowlton of the Vocational School of Milwaukee presented the first paper which was published in full in the September, 1922 issue of TRANSACTIONS.

After reading his paper as published, Mr. Knowlton added the following comments in concluding:

Mr. Knowlton: In conclusion we will say that successful carburizing requires a great deal of study, that we must use the strong carburizing materials wherever we may get them. We must be sure of their uniformity. If we make them ourselves, we must be very careful with our mixture. There must not be a great amount of chemical or strong carburizing agent of any kind in one part of the pot and not in another. We should take great care that pieces are not unduly close up to the top of the pot.

I might mention a commercial example of this that came to my attention a year or so ago, a firm was having trouble with soft spots in their work. They were making thrust ball bearings and were soft even after grinding. When we checked up on the grinding operation we found that the race side was ground first and a great deal more stock was taken off the opposite side than was taken off the ball race side. By grinding the under side, these races were hard where they had shown soft spots before. The decarburization was quite deep and by the aid of the microscope it was found that decarburization had occurred in the carburizing heat itself. On examining the plant conditions we found that they were using large boxes with nothing but a clay seal over the top. The boxes had been in use for a long while, and they were using a carburizing material containing salt, and there had been corrosion, until, in fact, there were holes in the sides of some of the boxes. These holes were plugged with clay and the top was covered with clay. They wanted to know why they got decarburization, and why they got soft spots on some of their work and not on other work. I will leave it to this test if it doesn't indicate that the probability was that toward he end of the carburizing heat, which was very long, 12 hours at 1700 degrees Fahr., there probably was a concentration of CO_2, which is decarburizing rather than CO, which is carburizing, near the places where the clay filled the holes and covered the tops of the pots. So that we should have well sealed pots as well. I thank you.

Chairman Boylston: We have listened to a very interesting paper by Mr. Knowlton. I believe that we cannot hear these points brought out too often, because there are so many variables in carburizing that one must keep all of them constantly in mind in the packing problem. If there are no questions or discussion on this paper we will pass on to the next paper, entitled *Case Hardening*, by A. H. d'Arcambal, metallurgist with the Pratt and Whitney Co., of Hartford, Conn.

Mr. d'Arcambal: Mr. Chairman and Gentlemen—When Mr. Dawe

asked me to prepare a paper for the convention this fall I started looking around for a subject that would create quite a bit of discussion. I do not think there are any two divisions of case hardening that would create more discussion than that of the chemical reactions taking place in the cyanide process of case hardening and impact tests on carburizing steels. There have been a large number of articles published recently on the value and significance of impact tests, etc., but on looking through the literature we can find no trace of where any work had ever been performed on the impact testing of carburizing steels either on samples in the carburized and hardened condition or on specimens treated by packing in sand instead of case hardening material, then double and single quenching. The first part of this paper deals with the chemical reactions taking place in the cyanide process of case hardening, the remainder of the paper giving the results of some Izod notched bar tests on several well known types of case hardening steels. Mr. d'Arcambal presented his paper as published in the September, 1922 issue of TRANSACTIONS.

Mr. d'Arcambal's Paper Corrected

Following the first sentence ending on the second line of page 1120 September, 1922 TRANSACTIONS the following sentence should have been inserted—Somewhat lower impact readings would have been obtained on the 6120 series if the carbon content had been the same as in the other alloy steels.

The sentence preceding the last paragraph of the paper should read—Not so much difference was noted in the fractures of the 6120 steel specimens after double and single quenching, only a slight coarsely grained structure being obtained on the specimens of this type of steel after single treating.

Chairman Boylston: I think you will all agree with me that Mr. d'Arcambal has added considerably to the available printed data, especially in regard to case hardened material, and especially has he added new information on the effect of nitrogen in the case hardening operation. In that last table I noticed that those specimens that Mr. d'Arcambal pointed out, which had a slightly greater hardness after single quenching, that is the second quench on the double quench specimens was about fifty degrees lower than in the single quench. Is it clear that the double quenched specimens had their case fully hardened? Might not that account for the slightly lower hardness?

Mr. d'Arcambal: I do not understand your question. You mean when you quench for case refinement only?

Chairman Boylston: Yes.

Mr. d'Arcambal: When carburized specimens are given only a single refining treatment a temperature slightly higher than is necessary to refine the case is usually used, so as to refine the core to a very small degree.

Chairman Boylston: Might it not be possible on the double quench that the second was a little too low to get the full hardening effect? That might be one way of accounting for the lower hardness in the double quenching.

Mr. d'Arcambal: You should obtain a greater hardening effect on the core on single quenching only, for you have used a higher tem-

perature than used for the case refining heat when double treating. We didn't attempt to refine the core to any great extent on the single quenched specimens, for that is not the usual practice.

Chairman Boylston: Are there any questions?

Mr. E. C. Brown: You mentioned that if you had not cooled your specimens in lime your results would have been higher. What reaction took place there in the lime?

Mr. d'Arcambal: It is our belief that if we had quenched the specimens, more of the nitrogen would have been retained in the combined form. This method we used gives only the iron nitride, and slow cooling seems to produce considerable free nitrogen. We did not treat the specimens after cooling in lime, for they were machinable.

Question: Did you pre-heat your test specimen before you immersed it in the cyanide?

Mr. d'Arcambal: No, we placed the specimens in the cyanide bath at somewhere around the desired temperature. As the samples cooled the bath slightly, a few minutes were required to bring the temperature back, the specimens were not actually at the temperature for the time specified. I might say that we found that the length of time in the cyanide did not affect the depth of case. We obtained around eight to ten thousandths case on all the samples but the time of immersion did affect the concentration of the carbon and the nitrogen.

Mr. Brown: I was just wondering why it wouldn't be a good idea to pre-heat all cyanide specimens.

Mr. d' Arcambal: As I stated, the time of immersion doesn't seem to make very much difference. The practice in one of the large plants I have recently visited is to immerse a large basket of work in the cyanide bath at around the desired temperature and of course the bath drops in temperature but as soon as the bath comes back to the required temperature they take the work out and quench it. Some lots might be left in the bath slightly longer than other lots. It depends on the rate of firing and also the amount of work you put in. They usually quench as soon as the bath reaches the temperature required, some parts being quenched in water and some in oil. I was surprised to note the hardness obtained on small parts quenched in oil. It was the opinion of a lot of people that you would have to quench cyanide pieces in water to obtain the proper hardness, but this company have obtained just as great a hardness oil quenching as water quenching.

Mr. Vanick: I was interested in the statement in the paper about the concentration of nitrogen. It seems to be misleading. That is, in the concentrated area, nitrogen appears as patches of pearlite. One might conclude from that that nitrogen in the form of these pearlite patches represents the most concentrated form of nitrogen compound. Now in the presence of carbon these patches are not a true iron nitrogen compound, but a compound of iron and carbon contaminated by nitrogen. We know pretty well, that in a high carbon steel, or a steel containing a progressive increase in carbon, that carbon will resist or impede the progress of nitrogen into the steel, and this resistance to penetration acts as a barrier which piles up the nitride or nitrogen in these higher carbon zones. This is borne out to some ex-

tent by Mr. d'Arcambal's results in which he shows an increase in carbon with an increase in nitrogen, and a very sharp decrease beyond that. But the main point I wish to bring out is that the nitride contained in the needle represents, as far as our experience has gone, a more concentrated form of iron nitride than that represented by the nitride patch or the pearlitic patch, and in fact, we have collected some circumstantial evidence; (It is not direct, on account of the very thin form of this nitride needle), that the needle type of nitride is a form of iron nitrite caught or trapped between the inter-cleavage or bedding planes, of the nitride needle), that the needle type of nitride is a form of iron nitride From that standpoint, if you consider the iron nitride needle as a very thin sliver of the compound of Fe_2N it is a more highly concentrated form of nitrogen than the pearlitic patch. Then, in making an analysis of this form of structure, of course we never do get the composition of the nitrogen compound when it is in the form of the nitride needles. That is, there is a great deal of surplus metal, which accompanies the sample, probably ferrite or whatever else is in the structure when we have used pure iron in the nitrogenization, of course the matrix is ferrite, which will bring down the total nitrogen to something like .05, or less, if the nitrogen is present in the needle form. But some structures which we have obtained on exposures to ammonia atmospheres have developed these thin nitride plates until they take on an appreciable width, and the entire width or the entire length of the grain is heavily filled with the compound of Fe_2N which stands all the way out, to the surface of the specimen.

Mr. d'Arcambal: May I ask if you attempted to harden the samples treated in ammonia gases, so as to see if you could obtain file hardness by nitrogenizing only.

Mr. Vanick: No, we haven't tried to investigate the hardening effect on these at all. The nitride is a very brittle substance, and any effort to test it with a file, I imagine, would either show very great hardness or it would scratch off much after the character of iron oxide or scale.

Mr. Bellis: There is one point I would like to bring out. I would like to ask Mr. d'Arcambal's opinion of the significance of the impact test in testing a routine test of carburized work. The reason I bring this up is because at Springfield Armory we found the results of the impact test rather misleading as a routine test. Possibly it was due entirely to the object we were carburizing. We were able to carburize a rifle receiver, and we consider that the high tensile strength, associated with a highly caburized case, added materially to the strength of the piece when it was subjected to an internal stress. I think it is generally considered that the case can add strength to a carburized piece. We found, though, that the carburized test pieces always gave very much lower readings of strength as indicated by foot pounds on impact than we found in actual practice. In other words, we would get twice as much strength in a carburized piece if we blew it up than we could in a piece that wasn't carburized. The impact test would show that piece to be only a small fraction as strong as the piece that had not been carburized. I would probably better state that again. In an actual performance test the receivers stood very much greater strength if they had been carburized. When it came to making an impact specimen from

the same piece, we found that the piece showed less strength after it was carburized. We attributed that to the fact that the nature of the impact test gave a brittle exterior and started a crack, and it was very easy to break the piece under a test of the nature of the impact test. I would like to have Mr. d'Arcambal give us his opinion on that point, as I think it may be misleading to take conclusions from impact tests as a test of efficiency of case hardening.

Mr. d'Arcambal: We have never used the impact test as a routine test for carburized work, but merely as a comparative test of different grades of steels given various treatments, as described in this paper. One would certainly expect greater strength on carburized and hardened parts made of alloy steel, than parts made of plain carbon steel, and the results obtained verified this. We also obtained higher impact readings on carburized specimens, double treated, as compared with single treated specimens, as would also be expected. While it is true that impact tests must be made on small specimens, one would expect that the material showing the highest resistance to shock in the form of these small specimens, would also show a correspondingly greater resistance to shock in larger sized specimens.

Mr. Bellis: We considered the rifle receiver as being a part subjected to excessive impact, and we were able to get 130,000 pounds pressure, as against 85,000 on a case hardened piece, greatly increasing the efficiency of the piece. Your sand treated pieces give greater strength than the carburized pieces. That might lead to the general conclusion that you cannot get strength in a carburized part.

Mr. d'Arcambal: We certainly would not expect material surrounded by a glass hard envelope to be as resistant to shock, as fairly ductile material not possessing a hard, brittle case. A small crack once started, would soon cause failure of the material. The impact test results obtained proved this belief in a very satisfactory manner. Tests on sand treated specimens were conducted merely to show the effect of the carburizing temperature and time on the different carburizing steels, double and single treated after the same treatment.

Mr. Bellis: Do I understand you consider the order of magnitude of the strength of the soft pieces and the case hardened pieces as given in the figures?

Mr. d'Arcambal: There was not so much difference shown in the alloy steels as in the plain carbon steels. Of course we expected that the plain carbon steels carburized and hardened would show higher impact values than were obtained but the carbon steel cases were considerably more brittle apparently than the alloy steel cases, thus giving very low impact readings.

Mr. Patterson: I would like to ask Mr. d'Arcambal if we are not overlooking some of the limitations of the impact method of testing? We know it is very important to have the given weight and specimens of a given size. If you use a different size specimen with the same pendulum, we get a result which we might possibly reduce to the standard size by making certain corrections. Now in service on a rifle part that was blown up by pressure, you will have of course a larger sized section than was used in the impact specimen, and the pressure necessary to blow it up. Tests of that kind, then, would be

equivalent to using a pendulum of a sufficient weight to break the specimen instead of using a pendulum of a constant weight, and in determining your residual swing of pendulum. If we make our investigations with different weight specimens or different sized specimens and different weight pendulums, we might get still more information from the impact testing.

Mr. d'Arcambal: Don't you believe, however, that the impact test is only a comparative test anyway? On the different steels we always use the same size specimens, the same striking distance, same pendulum etc., that is, everything is standardized. If a very tough steel was needed for an important part and we ran Izod impact tests on different steels and found, as in this case, that chrome vanadium steel showed the greatest resistance to shock and possessed the necessary tensile strength, etc., I certainly would feel it was the proper material to use regardless of the size of the part.

Mr. Patterson: If we would use different sized specimens and different weights of pendulum for a carbon steel and say determine the curve representing the corrections to be made from the size of specimen, and weight of pendulum, and then do the same thing with the chrome vanadium steel or some other steel, we might possibly get quite a different curve.

Mr. d'Arcambal: You would be nearer actual working conditions.

Mr. Patterson: If we got a very different curve for one steel than for the other, then it woudn't be fair to use the same size specimen for all steels and say "This steel is poorer than that," because maybe in the size used in service the correction curve would show that this poor steel in the small sized specimen may be a little better steel than a large sized specimen.

Mr. d'Arcambal: That point is very well taken. It is a very interesting proposition but when you come right down to it, the same thing might apply to a tensile test, for we usually pull the standard type tensile test specimen. It would be very interesting to obtain the different impact curves, because very little has been done on impact testing and what has been done has been very severely criticised. If some of the critics would do more actual practical work, I think we would obtain more information. I know that during the war in one of the airplane motor factories we found the impact value of very great importance on such parts as crankshafts and connecting rods. We were using S. A. E. 3140 steel on those parts. Of course the maximum Izod reading limit allowable took care of itself, because you had to meet a certain tensile strength and elastic limit, together with an 18 per cent minimum elongation and about a 50 per cent reduction of area. In one case a plane flying over Trenton crashed to earch because of the crankshaft breaking, killing the aviator. Since the plane contained our motor, the shaft was sent to us for examination. From four different places on the shaft we cut out tensile and impact specimens, and in every case the tensile specimens showed quite a bit higher results than the required limits, but the Izod values ran only 18 to 20 foot pounds, the minimum limit being 42 foot pounds. This was one of the first shafts turned out by the company and we could not find the original physical test report on the same. This shaft should of course have been rejected because of its low impact reading. I have heard there have also been many other cases where the tensile prop-

erties came well within the limits, but the Izod readings show so far below the minimum limit, with a coarse-grained structure, whereas on the tensile, a fine grained fracture was obtained. I personally have a lot of faith in Izod tests, or any other type of impact tests, although there really hasn't been much work done on this subject to date, especially on case hardening steels. The principal purpose of writing this paper on impact testing was not to obtain conclusive evidence as to the steels showing the highest resistance to shock because as stated in the paper, we were unable to make a direct comparison between the different steels, because the carbon varied four points from the lowest to the highest, but to learn the effect of single and double quenching on the Izod value, as well as to note the effect of pot quenching, etc. The brittleness produced by carbon being on the high side of the specification was also shown in these tests. As stated in the conclusion of this paper, it is hoped that the publication will result in the publication of more articles along similar lines.

Mr. Patterson: Where maximum impact value is desired, the use of lower carbon steel will give the best results. In every case where case hardened material is used, it is sometimes an advantage to have a little more rigidity or strength in the core. That is often the case on gears, truck gears, for instance, where the unit pressures are very high, and I know a number of truck people making gears who have a minimum hardness on the core so as to back up the case to withstand the high pressures.

I noticed in a comparison of the different steels that the nickel steels, the chrome nickel steels, the core had a considerably higher hardness than on the vanadium steels. I was wondering if Mr. d'Arcambal had run any impact tests in which the hardness of these steels had been the same.

Mr. d'Arcambal: Unfortunately, bath bars of S. A. E. 6120 steel showed the same low carbon content, and time did not allow us to obtain a new bar of this grade of steel.

Mr. Wickenden: The higher hardness you get, of course, the lower the impact value, and I should think that a comparison of the different rates could only be given after making an actual test, but in order to make a fair comparison of the impact values I should think it would be better to have the hardness of the core a little more even. This might be obtained by using a little lower temperature on the second quench on some of these steels. I know a number of people who for oil hardening 3.5 per cent nickel are using around 1350 or 1360 degrees Fahr. and in cases of water hardening they are going down to 1325 degrees Fahr. I think these lower temperatures would probably result in a slightly softer core, as it appears to me perhaps we are getting up just into the hardening range of the core. You will notice that in one case here, 1350 degrees Fahr. quench, on the second quench you have a hardness of 302, while at 1400 degrees Fahr. you get 370, and at 1370 degrees Fahr. you get 340. There is a gradual rise in hardness as you increase the temperature.

Mr. d'Arcambal: There is one thing interesting in regard to this discussion. On the S. A. E. 6120 steel marked *M,* we obtained a core brinell hardness of 255 to 265. On the S. A. E. 6120 marked *C,* a brinell reading of 295 was obtained without lowering the impact value as

compared with the *M* steel. The 295 brinell is not far removed from some of the brinell values received on the alloy steels, and in the case of the S. A. E. 3115 steel marked *E* in the carburized, pot cooled, and double quench condition exactly the same brinell reading was obtained but showed only 4 foot pounds Izod as against 11 foot pounds on the chrome vanadium marked S. A. E. 6120 *C*. In other words, we have a direct comparison of the impact value on two different steels with the same hardness, but with different carbon contents the S. A. E. 6120 showing much higher impact reading than the chrome nickel steel. These brinells, of course, were more or less difficult to obtain, as the specimens were only .450 inches in diameter, and we had to be careful to keep away from the carburized area.

Chairman Boylston: It seems too bad to interfere with an interesting discussion of this sort, but we have only fifteen minutes left of the session period and there is still another paper to be heard. We are certainly very grateful to Mr. d'Arcambal for this paper. Of course it is always within your province to write discussions later.

We will now have Mr. Ehn's paper on "Irregularities in Case Hardened Work Caused by Improperly Made Steel."

Mr. Ehn read his paper as published in the September, 1922 issue of TRANSACTIONS illustrating it by means of the stereopticon.

Chairman Boylston: We surely have chosen three very good authors this morning. Now is there any discussion on this extremely interesting paper?

Mr. Curran: My discussion on this tends to corroborate the results that Mr. Ehn has gotten in his work.

In the course of our examination of case hardened parts, and of tool steels in both the annealed and hardened conditions, we have often found it necessary to rely on the microscope to inform us as to the carbon content of the various zones in the case hardened specimens, or of the entire piece, where tool steels were under examination. In order to estimate closely the percentage of carbon present, it is essential that the structure of the specimen consist of lamellar pearlite plus grains of ferrite or networks of cementite, as the case might be.

We have observed that annealing at 1650 degrees Fahr. (i. e. heating to and cooling slowly from that temperature) serves to produce the necessary pearlitic structure with well formed grains or networks of excess ferrite or cementite, depending on whether the steel is below or above .90 per cent in carbon content. With such structures the carbon content can be estimated sufficiently accurately to aid in the interpretation of the structures observed in the original specimen, previous to annealing.

From time to time, however, we have observed structures after such annealing, in which the cementite networks were irregular and in which th lamellae of the pearlite grains were widely separated. These occasional departures from the usual type structures did not cause serious difficulty, and were usually ascribed to slight variations in annealing temperature or in rate of cooling, and were dismissed as unimportant. In the light of Mr. Ehn's disclosures, however, these occasional imperfect structures acquired a new meaning, which demanded closer investigation.

We therefore selected from our photo micrograph files samples of

tool steels which showed banded structures such as are usually ascribed to segregation of phosphorus or dissolved oxides, or which we had reason to believe to be of poor quality otherwise. These specimens we annealed at 1650 degrees Fahr. and in many cases we observed that previously banded material now showed two structures similar to those

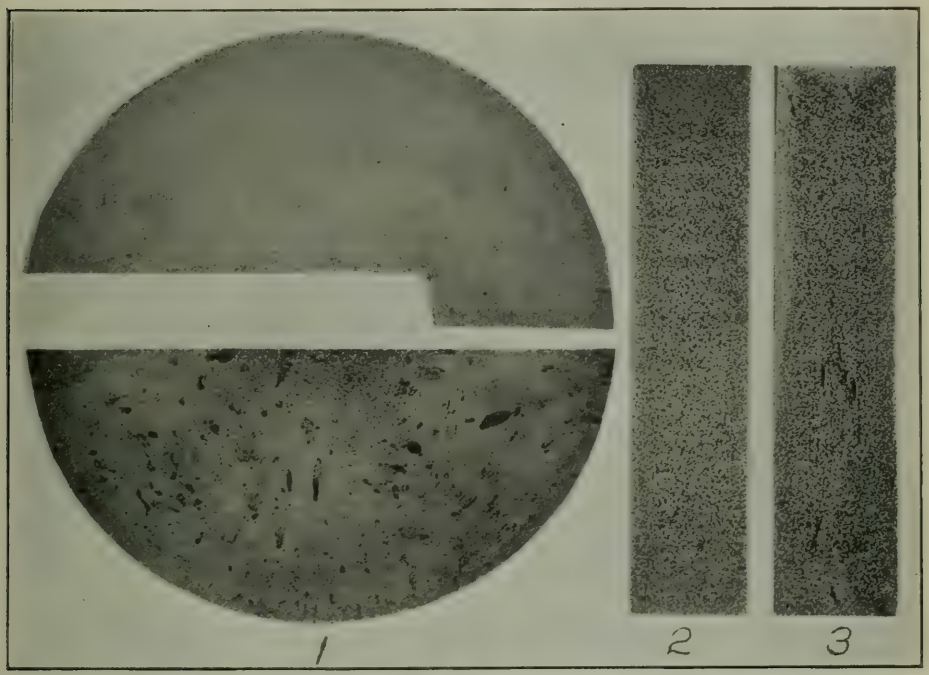


Fig. 1—Showing the Effect of Macro-Etching a Transverse Section of a 6-inch Round Bar of Tool Steel—Carbon Content .90-1.00 Per Cent. The Upper Half, Machined But Not Etched, Appears Perfectly Sound. The Lower Half, After Etching in Hot Concentrated Acids, Shows Numerous Deeply Pitted Areas, Indicating Serious Segregation. Fig. 2—Macrostructure of Open Hearth Tool Steel Identified as "Good." Fig. 3—Macrostructure of Open Hearth Tool Steel Identified as "Bad." Upon Quenching These Two Specimens Under the Same Conditions the "Good" Specimen Hardened to a Depth of Three Times that of the "Bad" Specimen. × 2.

described by Mr. Ehn as "Normal" and "Abnormal." In some cases the entire specimen showed an abnormal structure. Two lots of steel which we knew to be irregular showed striking similarity to the abnormal structure after the annealing treatment. These will accordingly be shown in the following figures.

Fig. 1 shows the effect of macro-etching on a transverse section of a 6-inch round bar of tool steel, in which the carbon content was in the range .90-1.00 per cent. The upper half, machined but not etched, appears perfectly sound. The lower half, after etching in hot concentrated acids, shows numerous deeply pitted areas, indicating serious segregation. Figs 4 and 5 show the structures observed in the bar as received, at a magnification of 500 diameters. These structures consist of lamellar pearlite and of spheroidal cementite and ferrite, respectively, and occur in adjoining bands in the same specimen. These structures are somewhat similar to the normal and abnormal structures described by Mr. Ehn. On annealing a section of this bar at 1650 de-

grees Fahr. the structures shown in Figs. 6 and 7 result. These occur in parallel adjoining bands as before, and consist of finely lamellar pearlite and coarsely lamellar pearlite, respectively. We believe that the wider separation of the lamellae in the areas represented by Fig. 7 is an indication of the presence of some abnormal condition, possibly, as suggested by Mr. Ehn, it indicates the presence of dissolved oxides.

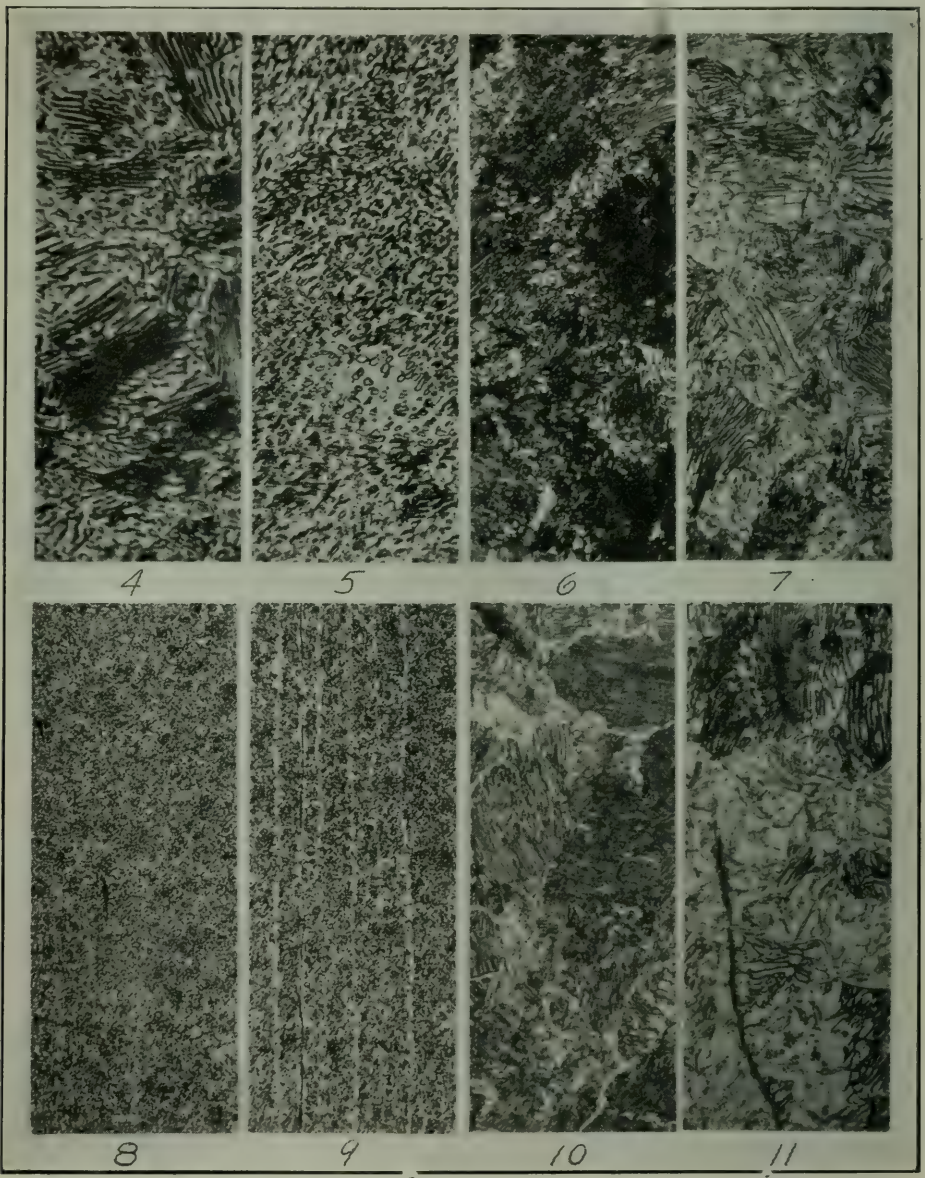


Fig. 4—Six-Inch Round Tool Steel as Received × 500. Fig. 5—Similar to Fig. 4. Carbon Content .90-1.00 Per Cent × 500. Figs. 6 and 7 Show the Results Obtained After Annealing at 1650 Degrees Fahr. × 500. Figs. 8 and 9 Show an Open Hearth Tool Steel of Different Heats. Carbon Content 1.10 Per Cent. Manganese .35 Per Cent × 100. Figs. 10 and 11 Show the Same Specimens After Annealing at 1650 Degrees Fahr. × 500.

A second example of abnormal structure is shown in Figs. 2, 3, 8 to 11 inclusive. These were taken from an investigation which we made of several samples of open hearth tool steel from different heats. These samples were classed as "Good" and "Bad" respectively, and our investigation indicated that the good sample was better than the bad in several ways. First, the macrostructure of the good sample, Fig. 2 as revealed by the macro-etch was better than that of the bad sample, Fig. 3. Second, on quenching specimens from both samples under the same conditions, the good sample hardened in for a depth three times that of the bad sample. Third, in the as-received condition, the microstructure of the good sample was free from the carbonless bands which were observed in the bad sample. These bands are usually ascribed to the presence of segregations of phosphorus or of dissolved oxides. Both specimens were perfectly spheroidized. Their structures, at 100 diameters, are shown in Figs. 8 and 9.

On annealing these two samples at 1650 degrees Fahr. Figs 10 and 11, the structures obtained exhibited marked differences. The good sample consisted of finely lamellar pearlite with well defined networks of excess cementite, whereas the bad sample consisted of coarsely lamellar pearlite with irregular, poorly defined cementite networks. This latter structure corresponds closely with those described by Mr. Ehn as "abnormal."

In the tests we have run on tool steels, we have used a simple anneal rather than a carburizing treatment. It seems probable that even better results might be obtained by actually carburizing the specimens. The differences in structure would probably be even more pronounced than those which we have obtained.

We believe that Mr. Ehn's carburizing test will prove a valuable aid in solving many of the difficulties which we encounter from time to time, and which in the past, after exhausting all ordinary means of investigation, we have been forced to ascribe to some obscure cause intimately related to the melting, refining, and pouring of the steel. Thus far it corroborates the results of the macro-etch, which until now has been probably our most instructive single test.

Mr. d'Arcambal: I would like to ask Mr. Ehn what experience he has found with Bessemer Screw stock. We know that such material contains considerable free and dissolved oxides. Our experience has been that we have always been able to obtain a well defined network after carburizing.

Mr. Ehn: My experience with bessemer screw stock is that usually the carburized structure shows exactly the condition you speak of, a large grain size, and at the same time a very pronounced disintergration of the pearlite. I consider some of the samples of this kind that I have seen as about the worst possible.

Mr. d'Arcambal: I was wondering if the fact that you had the network structure and disintegrated pearlite would cause you to have soft spots.

Mr. Ehn: I am pretty sure it will.

Mr. d'Arcambal: Screw stock is used extensively for carburizing and gives trouble at times, the same as S. A. E. 1015 steels, etc.

Mr. Ehn: I would say the reason probably is that some screw stock is bad, and some is not so bad.

Mr. d'Arcambal: There is another point about which I corresponded with you recently. On the S. A. E. 6120 steels we were unable to produce a network of cementite, although we could produce a cementite network on S. A. E. 5120 steels. Your paper I believe deals mostly with plain carbon steel.

Mr. Ehn: Yes, only with plain carbon steel. My experience has been that with say about one-half of one per cent of chromium or a little vanadium it is almost impossible to produce these real bad structures, so on the strength of our experiments we have changed our specifications for carburizing steel. Our specifications now call for from .30 to .50 chromium, and you kwow, most of you, that S. A. E. 1015 or 1020 often give trouble in the machining on account of the steel being too soft. The chromium makes it a little harder and makes it a little more free cutting, and I am also sure it helps so far as the carburizing and hardening is concerned.

Mr. d'Arcambal: Do you obtain a normal structure with that material?

Mr. Ehn: Yes, but it should be pointed out that there is no absolute certainty that a small percentage of chrome will always produce a good steel, if the furnace conditions are bad, but I believe it will help considerably.

Mr. d'Arcambal: We have had a hard time to find any chrome-vanadium steel that shows what you call a normal structure.

Mr. Ehn: Here is the point. A normal structure the way that I have described it here, will have to be confined to S. A. E. 1020 steel and with a different analysis, it is necessary to have other standards for abnormality and normality, however, I believe that they will be mainly along the same lines.

Mr. d'Arcambal: We sincerely hope that you will conduct experiments later on to show what is a normal and abnormal structure for alloy steels: because if you can develop such structures the same way you have developed the plain carbon steel. it will add greatly to the value of your important paper.

Mr. Ehn: I would say in answer to a previous speaker, that it is now a pretty well accepted view that ghostliness and banded structures are due to oxides in solid solution in the steel.

The carburized structure of a ghostline is exactly the same as that of a very abnormal steel. I think it is only reasonable to assume that if the abnormal structure in a ghostline is caused by oxides, that a uniformaly abnormal structure in steel is due also to oxides in solid solution.

A Member: Mr. Ehn is right when he says that oxides are now generally conceded as the reason for ghostlines, and his conclusions in regard to his abnormal steels are reasonable.

Mr. d'Arcambal: I would like to ask Mr. Ehn about the spring steel,—did you pack that in carburizing material?

Mr. Ehn: Yes, and we got just the structures and I showed you. The abnormal structures in regard to grain size can be brought out without carburizing, but even with low carbon material the effect is exaggerated by the higher carbon content at the surface, and with a high carbon tool steel I am pretty sure that, at least in the spring steels we have tested, we would not have been able to get any results without

carburizing. We have tested at least 15 or 20 of these spring steels by carburizing and our results checked very well with the results obtained in heat treating of these different steels.

Mr. d'Arcambal: Most of our tool steels run from 1.10 to 1.25 carbon.

Mr. Ehn: I don't know, I have had no great experience with steels of this analysis, but I am sure that the carburizing gases will have a tendency to bring out the normal or abnormal structures more clearly than if there is no such gases present.

Mr. d'Arcambal: Did you make chemical determinations for the oxides and nitrides in the good steels as compared with the poor steels?

Mr. Ehn: We tried to do that, but the results obtained were not very satisfactory. I showed for instance, a photograph here of two steels, one deozidized with ferro-manganese and the other deozidized with aluminum. In the case of aluminum as a deoxidizer the oxygen is probably contained as aluminum oxide, and there is hardly any way possible by which the oxygen content in that steel could be determined chemically, so chemical determinations of oxygen can hardly be of much value in this connection.

Mr. Styri: Were the structures obtained after quenching?

Mr. Ehn: The structures that I showed were not from quenched specimens. After quenching you can hardly see any difference at all. These structures are the structures after carburizing, and before quenching.

Mr. Styri: What is the effect of the temperature of carburizing on the oxides?

Mr. Ehn: I showed four pictures of abnormal steel carburized at different temperatures, the first showing a carburizing temperature of about 1700 degrees Fahr. In that case both the case and the core showed a fine grain. In raising the temperature the fine grain persisted up to about 1900 degrees Fahr. in the hypereutectoid zone close to the surface of the specimens, but farther in the grain starts to grow. At a still higher temperature, about 2000 degrees Fahr. and above, the grain grows, both in the area near the surface and farther in toward the core. At a still higher temperature of about 2200 degrees Fahr. the structure at the surface invariably consists of pearlite with cementite needles. Just exactly why that is I don't know, but it is a fact.

Mr. Styri: I meant between the normal and the abnormal steel.

Mr. Ehn: The normal steel shows already at 1700 degrees Fahr. a normal structure, and with a raised temperature there is no change except at very high temperature, when a needle structure is obtained. The change in structure occurs only in the abnormal steel, and with the steels used for this test there was no difference in the structure at 2000 degrees Fahr. between abnormal and the normal test pieces.

Mr. d'Arcambal: Do the steel mills object very strenuously to rejections because of abnormal structures?

Mr. Ehn: They did to start with, but we had an experience that convinced them. One steel mill sent us four or five heats and told us to pick out the bad ones. We picked out two, and they found out they were what they called *off heats* made during a night shift, and after that they did not kick about it.

Mr. Knowlton: On steel deoxidized with aluminum and low carbon

steel which is not to be case hardened, there has recently been an argument on electric steel, showing up a considerable amount of non-metallic impurities, carbon, from .22 to .28 per cent. One of the deoxidizers was aluminum. After repeated annealings some of these show, of course, not band impurities, but an alkaline network of original grains showing up white. Would that be due to deoxidization?

Mr. Ehn: I wouldn't like to off hand, to give an opinion.

Mr. Alvan Davis: I think I might say regarding the question of aluminum, aluminum I guess is universally used. Comparatively no steel is made without it. The difficulties you may experience I think would not necessarily be due to the use of aluminum. Of course it can be used in excessive amounts. The trouble I believe usually is due to excessive temperature.

Mr. Hildorf: I thought it might be interesting to know the application of this method of checking steel in an auto plant. We have had it in use new for nearly a year, and I guess anyone that has had anything to do with autos, or S. A. E. 1015 or 1020 steels occasionally get soft spots, but we haven't had it for months. On no parts have we failed to get away from soft spots, and that means 100 per cent on our stuff so far. We don't know how long it is going to last. We have gone now, I believe I am safe in saying, eight or nine months without a soft camshaft. That is, due to soft spots. We have had slips, of course, but that doesn't mean that it is caused by soft spots. Of course that doesn't mean they can get off on temperature out in the hardening room and we won't get them soft. But if they are soft it is usually half of the camshaft, or the whole shaft. And the same thing holds true with the other parts. Our check consists of taking samples at the same time that we take samples for chemical analysis. These samples are sent to the heat treating department and carburized at 1700 degrees Fahr. That is standard for our plant. These samples are then cooled in the box and a corner or section is cut out, with a saw, polished, and examined under the microscope. By that time, of course, chemical analyses will be run, and we decide at that time as to whether we will use the steel. Of course when one starts in with that, there will be more rejections for microstructure than there will be from analysis. It is very common to find analyses that nearly hit the center of our limits and still be very, very bad or very, very different, I might say, as to their microstructure.

As to tool steels, we haven't tried, as one of the speakers here mentioned, annealing. That is going into it very extensively, and didn't seem to get results, so we have been testing the tool steels in exactly the same way as we tested the S. A. E. 1015, by carburizing, and we find that it will work on steels of even 1.25 per cent carbon.

Chairman Boylston: Is there any further discussion or anything further any member would like to add? If not, we will declare this session adjourned.

DISCUSSIONS FOLLOWING PAPERS PRESENTED AT THE WEDNESDAY MORNING TECHNICAL SESSION OF THE ANNUAL CONVENTION, DETROIT, OCTOBER, 1922

THE second technical session held during the annual convention of the society in Detroit, Oct. 2-7 was called to order by the chairman, J. Fletcher Harper, research engineer with the Allis Chalmers Mfg. Co., West Allis, Wis., at 10 a. m. Wednesday, Oct. 4.

Mr. R. B. Schenck, metallurgist, with the Buick Motor Car Co., Flint, Mich., presented his paper entitled "Heat Treating in Lead." Mr. Schenck's paper was published in the September, 1922 issue of TRANSACTIONS.

In reading his paper Mr. Schenck commented as follows:

Of course, we all know what happens when material containing moisture is put into a lead pot or any kind of a molten bath.

In connection with that statement it should be borne in mind that what is meant is direct heating by resistance, using electrodes and not the induced current effect as in the Ajax Northrup Furnace.

Chairman Harper: I am sure there must be some discussion of this paper. We have a short time to take up that discussion.

Discussion of Mr. Schenck's Paper

Mr. McCleary: I think Mr. Schenck's statement was that in drawing the axle shafts at about 800 degrees Fahr. he used a caustic soda bath at about 700 degrees Fahr. I wondered if there was a chemical reaction that prohibited the use of the caustic soda on the top of the lead bath itself, thereby shortening the number of operations necessary.

Mr. Schenck: Mr. McCleary, we have tried caustic soda on the top of the lead. It looked good at first. We ran for three or four days that way and then oxidation took place. It gradually loaded up with oxide until we had the worst kind of a mess you ever saw. But using the straight caustic soda we, of course, had no such trouble. That was the thing that we worked out ultimately on that job. The caustic soda covering doesn't seem to be successful. The temperature of the caustic soda bath is held just below the temperature of drawing, the temperature of drawing being 800 degrees Fahr. and the temperature of the caustic soda 775 degrees Fahr.

Mr. McCleary: That is what I meant, if it could be used directly on top and get away from the double operation.

Mr. Schenck: That is a very natural suggestion, and we did try it, but it was't successful for that reason.

Mr. Patterson: I want to ask Mr. Schenck what kind of a pot he used for the caustic soda. Would a chrome alloy pot stand up?

Mr. Schenck: We use a steel pot. An alloy pot is not necessary. If you used a nickel chrome alloy at those low temperatures, you certainly wouldn't get your money out of it. The steel stands up so satisfactorily, providing there is no excessive overheating at any time, that it is the most economical proposition. The fact is a steel pot will last for six months or longer on that job.

Mr. d'Arcambal: Do you find that the alloy pots, like nichrome, etc., are more economical in heat hours than the cast steel pots or semisteel pots?

Mr. Schenck: In our experience we find on some jobs that the high priced alloy pots are more economical. On some jobs they are not. A good cast steel pot, if the temperature is down around 1450 or 1500 degrees Fahr. does for a number of jobs give the most economical service. On the other hand, when the temperature runs higher, and in cases where the output is very large and requires extremely severe firing, the reverse is true. It is a proposition in connection with which it is very hard to make a definite statement. Conditions vary so that what is true in one plant will not necessarily be true in another plant.

Mr. d'Arcambal: With cast steel pots running around .50 carbon (ordinary steel castings) we are obtaining an average of nine months, running at a temperature varying from 1400 to 1500 degrees Fahr. six days a week, and it seems to me that to obtain a comparatively efficient life with nichrome or any similar alloy we would have to run four or five years. We find that is not the case. We cannot get that much service.

Mr. Schenck: You certainly could not. If you are getting anything like that service out of a steel pot, you want to stick to steel.

Mr. d'Arcambal: One other question. Do you use the same temperature when you are treating shafts, etc., heating them in a lead bath, as you do if you were heating in a muffle furnace?

Mr. Schenck: Yes, we do. The fact is that at one time we used a semi-muffle underfired furnace. We switched from the furnace to the lead without any change of temperature whatsoever in the quench. When it comes to the draw, in some cases that is a different matter. Take continuous drawing furnaces. I have seen them with the temperature conditions such that in changing to lead you would have to change the temperature. But we have not had that experience, except with continuous furnaces. We have found we could switch indiscriminately from oven furnaces to lead.

Mr. d'Arcambal: We have always found in hardening tools of 1.15 to 1.25 carbon it is necessary to use a slightly higher heating temperature when we heat them in a lead bath than when the muffle furnace is used. The only way I can account for that is that the rapid heating might in some way raise your Ac points, and it is necessary to go to a slightly higher temperature. For example, we can harden a tool from 1390 degrees Fahr. in a semi-muffle type furnace, quenching in a brine, very satisfactorily, but you have a hard time getting that hardness if you heat it in a lead bath. I wondered if you experienced the same difficulty.

Mr. Schenck: I can't say we have. Our experience with tool hardening in lead hasn't been so extensive. While there is the possibility that it exists in tool steel, we have not encountered it in other steels.

Mr. d'Arcambal: Of course, you have slightly wider range in alloy steels.

Mr. Schenck: Was the time of heating the same in both cases?

Mr. d'Arcambal: Take for example a one inch tap. About three minutes in a lead bath is sufficient at a temperature of 1440 to 1450 degrees Fahr. whereas it will take 12 to 15 minutes in the muffle furnace.

Mr. Schenck: Do you suppose if you left the tap in the lead bath 12 to 15 minutes you would get the same hardness?

Mr. d'Arcambal: You would obtain the hardness, but you would

get a coarsening of the grain. Lead has such a high heat conductivity that it would be practically the same as soaking in a muffle furnace for 10 minutes or longer.

Mr. Schenck: In connection with transmission gears, we find that the gears require a longer time than three or four minutes in lead. The gears are made of S. A. E. 3145 steel. We find we have to hold them at least 15 minutes to get minimum distortion, and we also get 2 or 3 points higher in scleroscope hardness if we hold 15 minutes instead of only 3 or 4.

Mr. d'Arcambal: Of course, in that case you have alloys that you want to get in solution. With your S. A. E. 3145 steels do you quench from the draw in oil to get away from notch brittleness

Mr. Schenck: No, we haven't been donig that. We have never found it necessary. The draw is low 400 to 450 degrees Fahr. and the finished hardness is 70 to 80 scleroscope. We do quench, but not particularly to get away from brittleness; S. A. E. 3145 axle shafts and S. A. E. 1045 are all quenched from the draw, but it is more a cleaning proposition than it is a question of notch brittleness. At the same time, though, we feel that we are killing two birds with one stone

Mr. d'Arcambal: We have found practically the same as you have, that nothing can beat charcoal for covering a lead bath to prevent oxidation of the lead. We have tried all the different salt mixtures, but we obtain a much cleaner tool by having a charcoal covering on the lead than by any other method.

Mr. Schenck: That is our experience.

Mr. Curran: One gentleman has asked about the pots used with your caustic soda. I wonder if he isn't worrying about something we ran across sometime ago. In using nickel and nickel alloy crucibles for melting sodium and potassium carbonate mixtures, we found what the nickel alloys corroded very rapidly. They ate right through. Usually the corrosion was the most rapid at the surface, at the air line, the surface of the liquid. Of course, your caustic soda would change over in rather a short time to carbonate. I wonder if that is not what he has in mind. Of course, that corrosion occurs at temperatures of 1200 degrees Fahr. or in excess of that. We found that nickel alloys are not suitable for carbonate.

Chairman Harper: Our time is rather limited, and I think we would better proceed to the next paper, "Furnace Atmospheres and Their Relation to Formation of Scale," by Mr. G. C. McCormick, assistant metallurgist of the Crompton & Knowles Loom Works of Worcester, Mass.

Mr. V. E. Hillman will read Mr. McCormick's paper which was published in the August, 1922, issue of TRANSACTIONS.

Mr. Hillman: My assistant prepared this paper, and I shall attempt to defend it for him in the discussion which follows:

Discussion of Mr. McCormick's Paper

Chairman Harper: We have a communication here from Alvan L. Davis of Waterbury, Conn., in answer to Mr. McCormick's paper on certain points. Is Mr. Davis in the room?

Mr. Davis: Yes, I am here. I hadn't anticipated being able to come here. Mr. Chairman and fellow members: I was very much interested in the paper, but it seemed to me we ought to make a little distinction, perhaps, that hadn't been as clearly drawn as I would like to see it in speaking of neutral atmospheres. The distinctive qualities of a neutral atmosphere in a heating furnace are not in my opinion correctly defined by Mr. McCormick, who seeks to distinguish between what may be termed a theoretically neutral atmosphere, and an atmosphere which is practically neutral, or non-oxidizing. I do not believe that any such distinction should be made because a neutral atmosphere must be either, (1) an atmosphere free from any ingredient (not merely free oxygen) having an oxidizing tendency, and also free from any ingredient having a reducing tendency; or (2) it must contain both oxidizing and reducing ingredients, but present in such relative proportions as to secure a balanced condition at the given temperature under consideration and for the specified substance, such as steel, that is exposed to the atmosphere. That is, a neutral atmosphere must be defined as one that is in fact neutral, under such temperature conditions as exist for the operation in question.

It is well recognized, both in theory and in practice, that an atmosphere composed of CO_2 gas is powerfully oxidizing, to metallic substances, such as iron, at high temperatures; and the higher the temperature the more oxidizing is the action of CO_2, which tends to split up, yielding oxygen and CO. And the same is true of H_2O vapor. On the other hand, it is recognized that CO gas is reducing under certain conditions, and a mixture of CO and CO_2 gases may be made, where the oxidizing influence of the one is just offset by the reducing tendency of the other. The relative proportions of CO and CO_2 to give such a neutral atmosphere will vary with the temperature. A larger proportion of CO is needed to prevent oxidation (of iron) as the temperature increases. The experience of skilled hardeners of tool steel confirms this fact, by the necessity of feeding a greater excess of gas, or oil, to the burner in order to prevent scaling, when running the furnace at higher temperatures.

The proper control of the gases in an open muffle heating furnace will almost completely avoid the formation of scale, even when working at extremely high temperatures such as required for hardening high speed steel, where a temperature of 2350 degrees Fahr. is often used. At such a temperature but little CO_2 can be present if the hardened pieces are to come out white and clean. The very high proportion of CO present in furnace gases under such conditions is shown by the manner in which these gases freely burn when they come in contact with the air at the door of the muffle. A considerable outward pressure is maintained so that the movement of gas is always from the muffle door outwards, and no air from the room circulates inward into the muffle.

According to the equilibrium diagram for Fe, FeO, Fe_3O_4, CO, and CO_2, published in *Chemical and Metallurgical Engineering* based upon work reported by Baur and Glaessner in *Zeitung Physik Chem.* 1903 Pg. 354, the relation of CO to CO_2 (by volume) necessary in order to

avoid oxidation of iron, must be approximately as shown in the following table, for the various temperatures noted.

Temperature Degrees Cent.	Temperature Degrees Fahr.	Ratio of CO to CO_2 (By Vol.) to avoid oxidation of Fe to FeO)
680	1256	1.3 to 1
745	1373	1.4 to 1
830	1526	1.8 to 1
890	1634	2.3 to 1
935	1715	3.0 to 1

Chairman Harper: I do not know whether Mr. Hillman wants to reply to this or not. If not, a copy will be transmitted to him and Mr. McCormick and they can make written answer to it as they see fit.

Mr. Hillman: I wish to make a few remarks. I think a discussion will clarify the question. With reference to the practical reducing atmosphere, is that what you challenge, sir?

Mr. Davis: It seems to me rather unfortunate to describe as a neutral atmosphere one having a considerable proportion of carbon dioxide gas when it is recognized it is such a powerful oxidizing agent at high temperatures.

Mr. Hillman: The only reason we made reference to the practical atmosphere is to feature that atmosphere which the furnace operator tries to maintain by manipulating the valves. Admittedly there is only one reducing atmosphere, and that is a true reducing atmosphere, but every heat treating department has what they call a reducing atmosphere, and that is what we referred to as a practical reducing atmosphere, because we obtained it by practical results, by going to a furnace in the heat treating department and making an attempt to create a reducing atmosphere by juggling the valves. That is what you will find a hardener trying to do. These experiments were not carried on in a laboratory furnace. We went to the forge shop and asked the man to develop what he called a neutral or reducing atmosphere. After he was finished with the furnace, then we conducted our experiments. I think the point is well taken, however. You make reference to the fact also that if you have the proper relation of carbon dioxide to that of carbon monoxide, you may prevent the formation of scale. In other words, a certain ratio exists equivalent to a constant. Do you know what that constant is, sir?

Mr. Davis: I think perhaps it is best expressed in this last table, that is to say, the ratio would be a little different, the higher the heat the more you have to have of the carbon monoxide gas in order to avoid that effect.

Mr. Hillman: Do you know of any practical way whereby the CO_2 may be juggled so you can create an atmosphere that will not create scale?

Mr. Davis: In our case we are using gas, and not oil. We use a semimuffle type of furnace, originally built for oil, the type that everyone uses as a rule, I forget whether they happen to be Tate-Jones furnaces, but we turned them over and used illuminating gas that gave us perfect control under a certain mixture of air to start with, under pressure, and driven in, and we can actually bring out high-speed steel pretty nearly white out of that furnace.

Mr. Hillman: Do you want this body to believe that you can take

any kind of a furnace and juggle the valves and heat a carbon tool in there without scaling?

Mr. Davis: We haven't used this particular furnace for ordinary tool steels, that is done in a lead pot. But on high-speed steel where you get into the higher temperatures, it is used wholly. We did have similar burners, however, for this, to those which are used on some other furnaces, where you can practically eliminate it.

I might, while I am speaking, perhaps raise one point, and that is this: you have measured your oxidation by weighing the piece before and afterwards. You oxidize it and then you seek to free it by a very clever device, heating in your cyanide and going through your cleaning operation, but the question suggests itself whether when you put the oxidized surface into the cyanide bath, which is highly reducing, you don't actually reduce back, perhaps, some of the scale to the form of metallic iron.

Mr. Hillman: That is removed.

Mr. Davis: If it were actually reduced, in toto, back, then it wouldn't be removed. Then you would merely remove the oxygen and you wouldn't measure the oxidation really taking place. That might be shed off when you quench it, as you scale anything in quenching. So I raised the question as to whether that means of determining the amount of oxidation is fully accurate. It may be, but I should think some question might arise as to whether or not a thin film of oxide on the scale on the surface of the piece put into a cyanide bath might not in the cyanide bath be fully reduced back to the metallic condition, and virtually none of it shed off afterwards when quenched.

Mr. Hillman: When scale is formed it consists of an iron oxide. Is that right?

Mr. Davis: Yes.

Mr. Hillman: When you remove that scale and it is free from the metal, what bearing has it on the investigation if some of that iron oxide is reduced to metallic iron?

Mr. Davis: I presume you can take the oxidized piece and pack it with sufficient charcoal in any pipe and reduce it right back to the metallic condition. I am not sure whether you got rid of it here. You may have done the same thing, perhaps.

Mr. Hillman: We cleaned our specimens. I would like to go back to your other question again, sir, in preventing the formation of scale. I think it is a very good point if this gentleman can establish the fact that he can prevent the formation of scale by juggling the atmosphere in the furnace.

Mr. Davis: I think there is no doubt but what you would absolutely prevent it if you reached the proportions shown here, which, however, are very high in their content of carbon monoxide. We have come very close to doing that thing under the most exacting conditions, which are those of the high temperature, where you are treatting high-speed steel.

Mr. Hillman: How do you juggle the constant by allowing the inflow of air and city gas?

Mr. Davis: We have it absolutely under control with two valves. Our city gas is first mixed under pressure.

Mr. Hillman: What city do you refer to?

Mr. Davis: Our city is Waterbury, Conn. It is mixed, as I said, under pressure, with a reasonable amount of air, so it is, while not explosive, a very readily combustible mixture. We have an aperture which can be closed more or less which permits the sucking in of any amount of the atmosphere that we want. Now it will actually burn if we don't suck in any, or practically none, but it burns and produces almost pure CO gas. In other words, we could, I think, with that reach almost pure carbon monoxide with the addition, of course, of nitrogen and various other small proportions of gas there. In other words, we have a contrivance whereby we can reach furnace conditions that we never were able to approach before.

Mr. Hillman: Did you ever analyze the gas from the furnace?

Mr. Davis: No, but as I see it issue from the door of the furnace it burns freely. It is a combustible gas as it comes out of the muffle door.

Mr. Hillman: Well, in taking this up, the gentleman seems to contend that he can heat a carbon tool steel furnace without scaling. I suppose I will have to yield on that.

Chairman Harper: I will give this copy to Mr. Hillman and we will look forward to a full answer in the TRANSACTIONS of this gentleman's paper, also, perhaps, he will have some further reply. We have a few minutes for a little further discussion, but before going into that I want to say the committee, due to some mistaken arrangement in the program, has put another paper upon this program, and Mr. Ipsen will give his talk on the "Selection of Electrical Furnaces for Steel Treating" immediately following Mr. Vanick's paper, and this session is expected to run until 1:00 o'clock. There will be a few minutes more for Mr. McCormick's and Mr. Hillman's paper.

Mr. d'Arcambal: In the first place, I have never seen a furnace heating steel from 1400 up to 2400 degrees Fahr. whether oil-fired, gas-fired, or electrically heated, or induction or any other type where you can heat up parts and not get some scaling. We have tried all kinds of reducing atmospheres and every type of furnace, and while it is true on high-speed steel you get very little scaling, nevertheless, you do get some scaling, and any of you gentlemen, if you have any such furnaces, I would very much like to talk with you after the meeting.

On the second proposition, I notice Mr. Hillman, that all your specimens were cyanide treated before being calibrated, and weighed. Do you not believe that the carburizing and nitrogenizing action of the cyanide bath has some effect on your different grades of steel? In other words, have you compared the samples that were cyanide treated before calibrating and weighing with samples that were surfaced, ground, and then calibrated, weighed and tested?

Mr. Hillman: We didn't do that, sir. I hardly see where that is material. Could you just give us a little more information on the subject?

Mr. d'Arcambal: If you take a piece of steel and treat it in cyanide at 1450 degrees Fahr. for ten minutes, you have around .3 of a per cent of nitrogen going part way into the surface, and you will probably have

.30 or .40 per cent carbon. In that case you have a different proposition than you have with steel that is not so treated.

Mr. Hillman: I think that is a very good point. That is, you bring out the fact that you are likely to create an imperceptible film there which will not act the same under these various atmospheres as a piece of metal that was not given that treatment.

Mr. d'Arcambal: Of course, that might not have any action of that kind.

Mr. Hillman: I think that is a very good point. We will make an effort to surface grind some of them, as per your suggestion, and see what results we get.

Mr. Bellis: Mr. Davis' discussion has brought up a very interesting point. Shouldn't a neutral atmosphere be defined as one that is neutral to the material being treated? If we accept that definition of a neutral atmosphere, a reducing atmosphere will be one that will take the oxygen away from the steel, will it not? I would like to have Mr. Davis and Mr. Hillman's views jibe on that proposition. Will the reducing atmosphere reduce the scale? Aren't we using the wrong phraseology there, and shouldn't we start with some definitions of what is a neutral and what is a reducing atmosphere? I understand Mr. Hillman's use of the word has been purely shop.

Mr. Hillman: Those terms are admittedly wrong, they are misnomers, and I think if the A. S. S. T. would adopt a new nomenclature, it would do much toward clearing up some of the mistaken conceptions that exist with regard to a neutral and a reducing atmosphere. Those terms mean nothing at all. It is something like oxidized steel, oxides and nitrides of steel, I think those are also terms that need to be clarified.

Mr. Blasko: Isn't it possible that part of the scale formed was due to passing the pieces through the air before quenching them?

Mr. Hillman: I think that is perfectly natural to assume that that happened, that an imperceptible quantity of scale formed in transit from the furnace to the quenching tank. That is a well recognized fact, I think.

Mr. Blasko: Supposing you had taken a furnace and you tried to keep the same atmosphere in the furnace by passing the gases through. Suppose we had a sealed furnace with those gases in, and in passing the pieces through, naturally the first piece will have scale, to a certain extent. Isn't that true? The pieces that pass through after that would scale less and less, then, until finally we might reach a point where there would be no scaling whatever. Did you try to seal a furnace and pass pieces through it continuously?

Mr. Hillman: No, but I think you are to be complimented in reaching the keynote of the situation, that you are going to get different results from still atmospheres than you will in moving atmospheres. That is a very good point. These are only for gases that sweep through the furnace, and in all heat treating work you are going to have more or less convectional currents, and that is why we selected this atmosphere, because we thought it would approach practical conditions, as near as possible. But you will get entirely different results if you have still atmospheres in the furnace.

Mr. Blasko: I have tried that, sealing the furnace on both ends;

there is air in there, of course; then heat it and pass the pieces through. In about six or seven hours, I don't know just how many pieces were passed through, something like thirty or forty, but you could notice the oxidation was very pronounced at first, but it kept on getting less and less, and the last pieces were only discolored.

Mr. McCormick's reply to the questions raised by Mr. Davis are as follows:

Mr. Davis' exceptions to the definition of the neutral atmosphere are in the writer's opinion well taken. However erroneous the writer's definition is, Mr. Davis' attention is directed to the first statement in the original paper under the paragraph "Kinds of Atmosphere," which is as follows.

In furnace literature, frequent mention is made of 'oxidizing,' 'neutral' and 'reducing' atmospheres.

It is almost unnecessary to point out that the quotation marks about the words oxidizing, neutral and reducing are intended to indicate not the accurate technical meanings of the words but rather the meaning of the words as they are popularly though oftentimes erroneously and equivocally used.

It was the writer's purpose to bring out the fact that the so-called "neutral" atmosphere while balanced as far as combustion is concerned is nevertheless oxidizing to steel. On this point the apparent divergent views coincide exactly.

With reference to the adjustment of the gas-air ratio, Mr. Davis claims that he and his associates are able to bring high-speed steel from the furnace "pretty nearly white."

As the writer's paper does not consider the scaling of high-speed steel, it is necessary to forego extended discussion. It might be added, however, that Mr. Davis' success in eliminating furnace scale on high-speed steel is quite remarkable and not exactly in accordance with the experiences of some of his contemporaries.

Mr. Davis remarked further that "some question might arise as to whether or not a thin film of oxide on the scale on the surface of the piece put in to a cyanide bath might not in the cyanide bath, be fully reduced back to the metallic condition and *virtually none of it shed off afterward when quenched.*"

Mr. Hillman ably answered this objection and in reference to the italicised clause, the writer merely wishes to call Mr. Davis' attention to the fact that even though the scale may be completely reduced to metallic iron, nevertheless the reaction takes place at a temperature far below the fusing point of iron and consequently it is difficult to conceive of a union between the iron reduced from the scale and the original steel of the test specimen.

Mr. Davis' discussion presents the $CO:CO_2$ ratios for equilibrium, in the system Fe, FeO, Fe_3O_4, CO and CO_2. The ratios necessary to effect equilibrium as quoted by Mr. Davis are, if we are not greatly in error, results secured from the investigation of "still" systems. In attempting to utilize these ratios in heat treating furnaces, this fact is extremely important and should not be overlooked as it is generally admitted that the equilibrium constants for moving systems (the majority of heat treating atmospheres) are different from the equilibrium constants of still systems under identical temperature conditions.

The effect of the cyaniding on the response of the surface of the steel to scaling as cited by Mr. d'Arcambal is an important objection which undoubtedly may have some influence on the accuracy of the results of the investigation. However, in a research conducted in our laboratory some time ago, we found the depth of cyanide case induced in 10 minutes at 1450 degrees Fahr. to be .002 inches. These results were secured on test specimens which possessed only 1/3 the mass of the test specimens used in the scaling investigation.

Considering in addition to the variation in mass the correspondingly greater time interval which would be required to bring the test pieces to a heat at which the cyanide would be effective, it is doubtful if the depth of cyanide case induced in 10 minutes of the scale pieces would exceed .001 inch. The carbon and nitrogen in this case undoubtedly would influence the scale formation of the specimen in later heats but the error at best cannot be extremely large.

Mr. Blasko's account of the decreased scaling activity of a scaled furnace through which pieces of steel were passed comprises some valuable information concerning the scaling activity of furnace atmospheres.

A complete account of the work to which Mr. Blasko has reference would be an interesting contribution to the meager knowledge of the scaling activity of furnace atmospheres.

Chairman Harper: I am sorry, gentlemen, that our time is getting short, but I am sure that Mr. McCormick and Mr. Hillman will be very glad to answer any written discussion that you may care to present to them. The editor of the TRANSACTIONS is endeavoring to promote this idea of written discussions in order that the writers of these papers can answer them more fully after studying them in detail. He wishes me to urge you to send in written discussions on these various papers. I am sorry, but we will have to proceed to the next paper, which is by Mr. J. S. Vanick of the Bureau of Standards of Washington, on "Thermal Transformation of Some Chrome Vanadium Steels."

Mr. Vanick read his paper. The discussion of this paper will be published at the time when the paper is published in full in TRANSACTIONS.

Following Mr. Vanick's presentation, Mr. C. L. Ipsen, designing engineer, industrial heating department, of the General Electric Co., Schenectady, N. Y., presented his paper entitled "The Selection of Electric Furnaces for Steel Treating." This paper will be published at a later date in TRANSACTIONS.

DISCUSSIONS OF PAPERS PRESENTED BEFORE THE TECNICAL SESSION OF THE DETROIT CONVENTION OF THE SOCIETY, FRIDAY MORNING, OCTOBER 6

THE Friday morning technical session of the society's convention held in Detroit Oct. 2-7 was called to order at 10 a. m. by Chairman R. S. Archer, metallurgist with the Aluminum Company of America, Cleveland.

Chairman Archer: We have two papers on the program this morning, one by Mr. Knerr of the United States Navy on "Duralumin Forgings" and one by Dr. Anson Hayes, Professor of chemistry at Iowa State College and Professor W. J. Diedricks, assistant professor of mechanical engineering, on the "Rapid Graphitization of White Cast Iron with a Discussion of the Resulting Products."

Mr. Knerr is not with us having been kept away, I believe, by illness and he has asked me to present an abstract of his paper. The original paper is considerably longer. It is mostly a summary of information from various sources on aluminum forgings, their properties and heat treatment.

Mr. Archer read the abstract of Mr. Knerr's paper interpolating the following remarks during and after the reading.

In connection with the relative stiffness of parts made of steel and of aluminum alloys, it is to be remembered that the low modulus of elasticity of aluminum is offset by its low specific gravity and the fact that the stiffness of a beam is a function of the fourth power of its linear dimensions. The result is that if we design beams of similar rectangular cross section, for example, of steel and of aluminum alloy in such a way that the stiffness of the two beams is the same, then the weight of the aluminum beam is 60 per cent that of the steel beam. This applies to any alloy of aluminum and steel of any composition, since the elastic modulus is not appreciably affected by small changes in composition or by heat treatment or mechanical working.

One of Mr. Knerr's statements may create a misleading impression. He states that duralumin ingots weigh from 50 to 75 pounds. This might give rise to the impression that forged or rolled pieces of greater weight could not be manufactured. As a matter of fact, we have made ingots weighing up to 180 pounds for large forging and could make them larger if called for.

A number of the forgings now being made commercially of high tensile aluminum alloys come under the class of automobile hardware and are used largely because of the fine finish which can be imparted to them and which resists corrosion and tarnish very well. Such parts are largely substituting nickel-plated parts.

It may be mentioned that duralumin of the composition used for rolled and forged products is not a suitable alloy for castings even when heat treated. The strength and especially the elongation are disappointingly low. Other compositions can be used which with the proper heat treatment give very much stronger and rougher castings.

The long sections used in the construction of airplanes and dirigibles are usually made by forming a ribbon of sheet. The ribbon is coiled and heat treated in this shape and then shortly after quenching it is formed into the desired section before it has had a time to harden

greatly by aging. After being thus formed it does not require further heat treatment so the problem of warping is very much simplified.

While freshly quenched duralumin sheet is fairly easy to form cold, the annealed sheet is still easier to work and will stand reforming operations not possible with the quenched material. If the annealed material is used, however, it must be heat treated after forming which involves the possibility of warping. In case of assembled structures held together by rivets the subjection of the piece to heat treatment would cause the rivets to lose their hold.

Mr. Knerr recommends the salt bath for the heat treatment of duralumin and as a means of heating the metal for forging. A salt bath has many advantages especially for heating thin sections like sheet. It has serious disadvantages, however, in the case of larger pieces and particularly when heating for forging. In the latter case, the molten salt which adheres to the metal spatters when the metal is forged and is apt to inflict painful burns. An electric furnace is preferable to salt for heat treating forgings and for heating preliminary to forging although the latter operation can be conducted with a less expensive furnace.

The fact that the mechanical properties of the aluminum alloys do not deteriorate at very low temperatures, but rather improve is considered rather important in the construction of aircraft where very low temperatures are apt to be encountered in flight.

The electric welding of duralumin does not appear to be commercially successful at present. Gas welding appears to be the best. Mr. Knerr has contributed an article to the *Automotive Industries* on the method of welding.

If there is any discussion or any questions they will be taken down and forwarded to Mr. Knerr. In the meantime, I will be glad to answer any questions which may seem proper in this connection.

Mr. McCleary: I would like to ask, if it is the proper place to ask, what physical or chemical changes take place during the aging.

Chairman Archer: The theory of heat treatment and aging is quite fully discussed by Mr. Knerr in his paper, but I have omitted this discussion at present, because it is rather involved and the time is too short to enter into it fully. Briefly, duralumin in the freshly quenched conditions contains copper and magnesium silicide in solid solution. This solid solution is unstable and decomposes during aging with the precipitation of the hard compounds $CuAl_2$ and Mg_2Si in the form of very small particles. This precipitation is held to be the cause of age hardening.

Mr. Wise: What is the function of manganese?

Chairman Archer: The practical effect of manganese is to increase the tensile strength. It forms a hard compound $MnAl_3$ which hardens and strengthens the alloy. There is also probably a grain refining effect.

Mr. Wise: Iron does not do the same thing?

Chairman Archer: No.

Mr. Curran: What is the temperature range of extrusion. Is it in the forging range.

Chairman Archer: The small tubes just passed around were ex-

truded cold, but the usual practice on larger pieces is to extrude hot.

Mr. Curran: In what type of furnace are the long pieces heat treated.

Chairman Archer: The long sections are heat treated in the form of a coil before being formed, using a salt bath.

Mr. Curran: Assuming that you would have a long piece of 5 or 6 feet, how would it be heat treated?

Chairman Archer: If you had thin metal and a large salt pot, I would say that would be the most economical way to handle it, but with a section of any thickness I should prefer an electric furnace.

Mr. Curran: Another question with regard to welding thin sheets. Is it possible to weld thin sheets, say as thin as 0.014 inch.

Chairman Archer: I believe it is possible, although the difficulty probably increases as the sheet becomes thinner.

Mr. Curran: Have you had any experience with spot welding of the thinner sheets?

Chairman Archer: No. Spot welding has been attempted by a number of firms but I have not personally encountered any satisfactory results. The spot welding is hindered by the presence of thin films of aluminum oxide on the surface of the metal.

Mr. Harder: I want to inquire if there is any difficulty experienced in design where a number of the parts are of duralumin and some of the parts are of steel because of the difference in the modulus of elasticity.

Chairman Archer: The difference in elastic modulus must, of course be recognized in design. With proper allowance for this factor no difficulty should be experienced.

Mr. Percival: Have any members of the society had experience in extruding the material and what is the character of the die they used. We have tried to extrude the material on mandrils and have found difficulty from the metal sticking to the mandril.

Chairman Archer: If there is anyone here that could throw any light on this question we would be very glad to hear from them.

(No response)

Mr. Percival: The same thing holds with regard to pure aluminum.

Chairman Archer: Are there any other questions on the dualumin paper?

(none)

There is one further topic on which I should like to make a few remarks and that is on the name "duralumin." This, as has been indicated from Mr. Knerr's paper, is a German trade name derived from the name of the factoy that originally made the metal in Germany. It is objectionable to use a trade name to designate a class of alloys. The alloy to which their word duralumin refers is rather definitely an alloy containing aluminum, copper and magnesium and usually manganese. This is not the only high tensile aluminum alloy suitable for rolled and forged products. Therefore, I would suggest that in referring to high tensile aluminum forgings we should say aluminum alloy forgings rather than duralumin forgings. Duralumin is not the only alloy available and it is just as illogical to use that term to cover all forgings as it is to designate all steel connecting rods by the trade name of one alloy steel

such as chrome-molybdenum or U. M. A. Duralumin is merely one of a number of aluminum alloys suitable for forgings.

Another point in this connection is that in the case of aluminum alloys as in the case of steel, the cost of fabrication increases in general with the physical properties required. You do not ask for high chrome nickel steel forgings when straight carbon steel forgings will do just as well. Likewise, if a user specifies higher physical properties than he actually needs in aluminum forgings he is apt to pay a higher price than is necessary. For example, a tensile strength of 60,000 pounds per square inch is not required for an automobile door handle.

The next paper on the Rapid Graphitization of White Cast Iron will be presented by Dr. Hayes.

Dr. Hayes: I realize this probably is outside of the field of most of your interests, and realize also the position I am putting myself in in presenting a paper on this subject. It has been said that whenever a young genius comes forward with a rapid method of graphitization, we always take his statements with extreme misgivings. I wish to state also, that being in connection with an educational institution, we realize that we are apt to be a few jumps behind industrial development, and I wish to state also that a paper written by H. A. Schwartz of the National Malleable Castings Company, which appeared in September of this year presents some of the material which I will present in this paper. However, I believe there are some considerable points that will be of interest, in addition to what has already been presented by other workers.

Dr. Hayes read his paper.

The discussion of this paper will appear at the time when the paper is published in TRANSACTIONS.

Steel is Steel

(*Continued from Page* 306)

or better. This is not conjecture but fact based on actual occurrence, and the difference in practice represents an important item in the production of heat treated parts.

Steel is steel; but it requires study and investigation, separation and selection, carefulness in handling, judgment in the choice of stock, determination of proper treatment and accuracy in carrying out that treatment—then may profitable production be maintained with a product that will be a source of pride to the manufacturer and of satisfaction to the consumer.

CHARACTERISTICS OF AIR COOLING CURVES

By E. J. Janitzky

Radiation and Convention

BY COOLING a solid body from any given temperature, under the assumption that it does not possess transformation points similar to those of steel, we note that, at the start, as the metal has the highest temperature, only a short time is required for equal temperature drop, whereas with further drop of temperature the time is considerably increased. The temperature drop of steel or iron, for instance, will not be continuous, but will show interruptions or retardation at certain points.

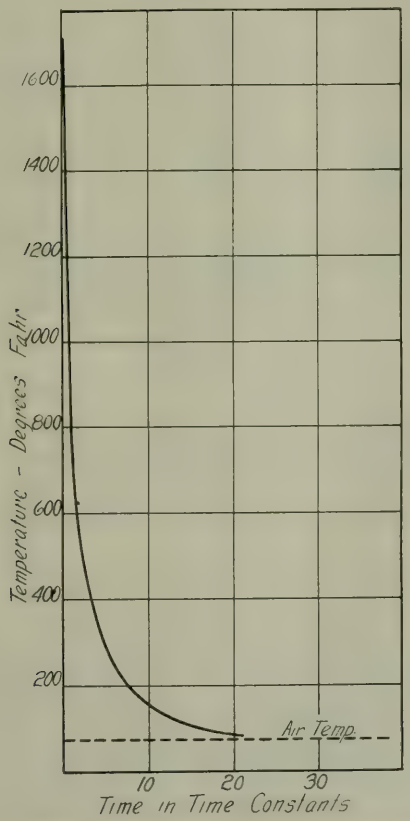


Fig. 1—Chart Replotted from Time-Temperature Chart Plotted on Instrument

By plotting the time as the abcissa and the temperature as the ordinate we obtain a curve of the shape as shown in Fig. 1 which was replotted from the spherical temperature recording pyrometer chart of Fig. 2. These curves are generally referred to in the pertaining literature to be of logarithmic char-

A paper written for TRANSACTIONS. The author, E. J. Janitzky is metallurgical engineer, The Illinois Steel Co., South Chicago, Ill.

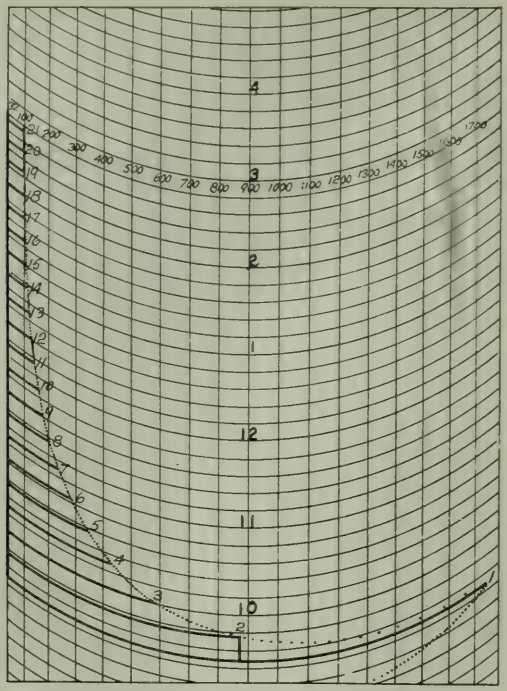


Fig. 2—Time-Temperature Chart as Recorded on Instrument.

acter. The writer, however, does not intend to interfere with the prevalent contentions but endeavors to present his observations on cooling curves in air (radiation, convection) and their characteristics.

Before going into the subject the three different processes of heat transfer may be recalled:

1. *Convection is the transfer of heat by moving matter, for example, by hot air which can be felt rising from any hot body.*

2. *Conduction is the flow of heat through and by means of matter unaccompanied by any motion of matter, for example, the passage of heat along an iron bar one end of which is held in fire.*

3. *Radiation is the passage of heat through space, but without the necessary presence of matter, for example, the passage of heat through the vacuum of an incandescent lamp.*

The writer cooled cylindrical nickel specimens from different maximum temperatures in air as shown in the accompanying charts. The size of the specimen was 7/8 inch in diameter and 2.5 inches in length with a central hole of 7-32 inch half the length of the specimen for inserting the pyrometer couple. The couple was of nickel chrome and connected to a time temperature recorder as made by the Brown Instrument Company of Philadelphia, and with a duplex thermo-couple usually used for thermal analysis. The heating was performed in a circular resistance electric furnace of 2.5 inches in diameter and 3 inches in depth. The travelling speed of the paper was

.22 inch per 3.5 minutes—.22 inch represents the small time interval spacing on the chart.

It was found that the results of time temperature curves of the air cooling specimens, lend themselves to simple calculation and the data obtained are very useful in metallurgical cooling problems. The salient point

Table I

Size of Nickel Specimen ⅞" Diameter and 2½" in Length

T° Maximum Temp.	Temperature As read off Degrees F.	Temperature t^0 $t^\circ = \frac{T^\circ}{t+1}$ Temperature As calculated Degrees F.	t As elapsed in constants t=.295 In.=4.69 Minutes	Time T $T = tm$ In Minutes
1750 ° F.	1750	1750	0	0
	1170	1170	.5	2.34
	875	875	1	4.69
	580	585	2	9.38
	445	437	3	14.07
	340	350	4	18.76
	285	290	5	23.45
	240	250	6	28.14
	210	218	7	32.83
	180	194	8	37.52
	160	175	9	42.21
	90	87	19	89.11
	85	83	20	93.80
	87	80	21	98.49

Air Temp. 80° F.

Table II

Size of Nickel Specimen ⅞" in Diameter and 2½" in Length

Maximum Temp.			t=.885 In.1=4 Min.	
540° F.	540	540	0	0
	370	360	.5	7
	270	270	1	14
	170	180	2	28
	130	135	3	42
	105	108	4	56
	95	90	5	70

Air Temp. 74° F.

of the mathematical procedure is the adoption of a time constant, or in other words to ascertain the time which is required to half way cool the range from its maximum temperature to zero in the Fahrenheit scale. Having the constant in linear length and plotting it in multiples from zero on the X axis which represents the time co-ordinate, one obtains by projecting the units of the time constants as ordinates, as visible on Figs. 2 and 3, until its intersection with the actual curve whose points coincide with temperature numerals t° derived by dividing the maximum temperature T° by the amount of time constants t or their fractions elapsed during cooling, plus one, or t+1.

The formula mathematically expressed will read:

$$t^\circ = \frac{T^\circ}{t+1}$$

and the actual time T=tm, m being the time of the time constant in minutes, seconds or hours, t the amount of time constants elapsed. The time constant

increases with decreasing of the maximum temperature to which the body was heated before cooling, and may be derived from a standard curve for lower temperatures, by projecting the temperature for which it may be desired on the X axis and drawing half way through the temperature range a parallel which intersects the standard curve and the ordinate. The linear

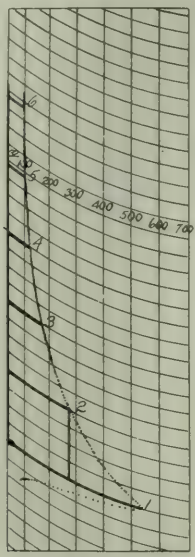


Fig. 3—Time-Temperature Chart Plotted on Instrument

length represents the time constant for the particular temperature. Obviously the time constant holds good only for the same shape, size and mass.

For larger masses of geometrical similarity, the time constant increases in a manner as the surface per cubic inch decreases with increased sections, namely hyperbolic. Tables I and II give actual and calculated data obtained from 2 curves.

In respect to specimens where the curve is interrupted by a transformation point, one has to deal with two curves, namely, the one representing the temperature drop from the maximum temperature to the start of the transformation, and the other one setting in at the temperature after the heat evolution is completed to atmospheric temperature.

Both curves practically represent a unit, which is, however, interrupted by the time of the transformation period, and the lower part of the curve. Obviously this is only a shifting parallel to the time axis, which represents the amount of time required in passing through the transformation point.

In concluding, the writer wishes to state, that by using the time constant as outlined above, reasonable data can be obtained of bodies cooled to ordinary atmospheric temperature.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

NEW QUESTIONS

QUESTION 56. *Which is the best method of producing large forgings, pressing or hammering?*

QUESTION 57. *Does repeated heating just above the critical range with subsequent quenching of a steel specimen injure its physical properties?*

QUESTION 58. *What is the cause of brittleness resulting from the carburizing of steel?*

QUESTION 59. *Is a sulphur content of .067 per cent detrimental to the proper carburizing of a low carbon steel having low a manganese and phosphorus content?*

QUESTION 60. *What is the cause of distortion of carburized parts of regular conformations?*

ANSWERS TO OLD QUESTIONS

QUESTION NO. 27. *What is the function of the high phosphorus and the high sulphur content in the so called automatic screw stock steel?*

QUESTION NO. 35. *What is the difference between red annealed and blue annealed sheet steel?*

QUESTION NO. 38. *What regulations are recommended to reduce the fire hazzard of quenching tanks?*

QUESTION NO. 48. *What are dendrites and how may they be detected?*

QUESTION NO. 49. *Can dendrites be removed through a proper heat treatment?*

QUESTION 51. *What are the causes of black fractures in high carbon tool steel?*

ANSWER. By H. A. Schwartz, Manager of Research, National Malleable Castings Co., Cleveland, Ohio. The separation of secondary graphite (temper carbon) at some stage of heat treatment has been dealt with in the August 9 issue of *Chemical and Metallurgical Engineering* by A. W. F. Green, in a paper entitled "Black Fractures in Carbon Tool Steel."

This paper by Mr. Green was discussed by several metallurgists in subsequent issues of *Chemical and Metallurgical Engineering.*

QUESTION 52. *Is the Brinell hardness number of a given piece of steel, an accurate measure of its machinability?*

ANSWER. By H. A. Schwartz, Manager of Research, National Malleable Castings Company, Cleveland, Ohio.

The machineability of no material can be inferred from its Brinell number. It is probably true that a given material heat treated to a given Brinell number will always give the same machining properties. Examples where Brinell number does not go with machineability are Hadfield manganese steel, having only moderate Brinell hardness but an indefinitely high resistance to cutting. Malleable cast iron and wrought iron have identical Brinell numbers but the former machines much more freely.

QUESTION 53. *What is the composition of the so-called semi-steel?*

QUESTION 54. *Is it possible for a piece of commercially pure iron in contact with a piece of high carbon steel, to absorb carbon from the steel?*

ANSWER. By H. A. Schwartz, Manager of Research, National Malleable Castings Company, Cleveland, Ohio.

The ability of commercially pure carbonless iron to absorb carbon from a specimen of steel when maintained in close contact with the steel at temperatures above the Ac_3 point, has often been demonstrated. Perhaps the most recent demonstration on a quantitative basis was performed by Messrs. Klopsch and Roberts, students of Case School of Applied Science who were carrying out this work in the writer's laboratory.

QUESTION 55. *What are the causes of soft spots in the carburizing of steel?*

ANSWER. While this question is one of a general nature it must necessarily be answered in a general way.

The most frequent cause of soft spots is faulty heating during the carburizing period. Close observation invariably discloses the fact that the soft spot occurred where the temperature would be the lowest inside the carburizing box.

As an example—in a certain plant manufacturing gasoline motors, it was

the practice to pack 500 piston pins in a single carburizing box. Almost a fixed percentage of them were always rejected for softness and yet the practice was persisted in, in spite of the constant loss, because "production must be kept up."

A survey of the difficulty showed that the method of packing, was responsible for the trouble. The pins were packed in such a solid mass that uniform diffusion of heat throughout such a mass, within the few hours allowed for the operation, was impossible. Soft spots are more generally met with than entire surface softness and usually are more easily explained.

Soft spots may also be caused by the parts coming into contact with each other through careless packing, or they may occur in parts placed near the top of the box with too little carburizer over them to allow for the shrinkage that always takes place, especially when the carburizer is new.

One of the frequent causes for soft spots is due to decarburization which may possibly occur during long reheating in an open furnace preparatory to hardening. If there is an excess of air in the reheating furnace there would be a tendency for the carbon to be burnt out of the surface of the steel.

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

SERVICE FOR MEMBERS

The Library Bureau of the American Society for Steel Treating is operated to give to the members quickly, reliably and at the minimum expense the following service:

1. A complete copy of the magazine article referred to in any periodical you may be reading.
2. A Translation of foreign articles that would help you with your work.
3. A list of references to books and articles on any metallurgical subject.
4. Informing the members of new articles of interest to them as an engineer.

The Library Bureau makes the entire field of literature available to every member, distance is eliminated, for it will copy the desired information and send it to you. It also helps the busy man by supplying information without any expenditure of his time. The charge for this personal work is merely its cost.

The Library Service does not obtain any profit from the work, but does this to make the information contained in the large libraries with which it has connection available to every member. The rates are as follows:

Photo Print Copies of articles, drawings, etc., 25c per 10 x 14-inch sheets.

Searches, abstracts, etc., $2.00 an hour.

Translations, $6.00 per thousand words for French or German: $7.50 and upwards for other languages.

Reference card service, giving reference to current magazine articles, $10.00 a year in advance, and 5c for each card mailed.

Members desiring to avail themselves of this service should address Library Bureau, American Society for Steel Treating, 4600 Prospect Ave., Cleveland, Ohio.

AUTOMATIC ELECTRIC TEMPERATURE-REGULATING SYSTEM FOR FURNACES. By I. William Chubb, editor European edition, *American Machinist*, Vol. 57 No. 18.

The above article gives an account of the temperature controls used by Adolphe Saurer in their plant at Switzerland.

In the coke and coal heated furnaces the temperature is automatically controlled by varying the position of the dampers; where gas, oil and electricity are employed it is somewhat different.

The system controls six furnaces working equally well, whether the temperature

in these furnaces is the same or different, the heat being varied by controlling the drafts in the chimney with a slide, which is itself controlled by the electric regulating device described in the article.

STEEL REQUIREMENTS OF THE AUTOMOTIVE INDUSTRY. By Harry Chandler, Metallurgist the C. H. Wills Co., Marysville, Mich., in *Iron Age,* Vol. 110, No. 18, pages 1136, 1137.

The author points out that the mechanical characteristic of the steel in automobile manufacture is of prime importance. A classification of the various parts in an automobile and the group each represent is given, as well as the test used to determine the mechanical properties.

The importance of heat treating is emphasized and the statement made that the physical properties of steels are a direct function of the drawing temperature. The author points out where alloys steels are best adopted for certain parts.

THE ELECTRIC FURNACE IN REFINING IRON AND STEEL. By Dr. John A. Mathews, Pres. Crucible Steel Co. of America in *Iron Age,* Vol. 110, No. 18, pages 1127-1130.

The author gives the present status of the electric furnace and also reasons for the world-wide expansion in the use of electric furnaces. The importance of clean steel is forcibly presented, and the part played by the electric furnace in producing this grade of steel is also brought forward. The mechanical and electrical refinements that have been made are mentioned as well as a discussion of the versatilities of the electric furnace.

NON-METALLIC INCLUSIONS AND FERRITE SEGREGATIONS IN STEEL. By E. G. Mahin and H. W. Botts, Department of Chemistry, Purdue University, in *Chemical and Metallurgical Engineering,* Vol. 27, No. 20.

This paper points out that the segregation of ferrite about non-metallic inclusions is a phenomena that has long been familiar to metallurgists. However, differences in opinion of observers as to the cause of these segregations are prevalent. Most of the theories that have been proposed are familiar to students of metallurgy. One of the authors points out that several of the theories advanced do not account satisfactorily for all of the observed cases. It is pointed out that manganese and sulphide are present in steel surrounding a sulphide inclusions that cause the precipitation of ferrite shells.

These tiny inclusions have much to do with the locus of the excess ferrite.

THE PROBLEM OF PIG IRON SPECIFICATIONS. By Wm. R. Webster, Consulting Engineer, Philadelphia, Pa., in *Raw Materials,* November, 1922.

This paper discusses the chemical requirements of pig iron ordered by various foundries making the same grade and weight of castings, showing that the specifications and requirements vary considerably and cause the blast furnace men unnecessary trouble as they are called upon to make several grades of pig iron for the same weight and grade of casting.

The author summarizes the various grades of pig iron which can be obtained in the United States.

HANDLING MATERIAL IN AN AUTOMOTIVE PLANT. By M. R. Dennison, Studebaker Corporation, South Bend, Indiana, in *Iron Age,* Volume 110, No. 20, November 16th, 1922.

This article outlines the system in use at the Studebaker plant for the handling of automotive material. It is illustrated with numerous photographs taken throughout the plant showing tractors hauling trains of boxes throughout the plant. Also conveyor devices and overhead cranes.

INVAR, ELINVAR AND OTHER NICKEL STEELS. No. 2. By Wallace Dent Williams in *Raw Materials,* November, 1922.

This is the second of a series of articles dealing with the development in the metallurgy of nickel steels. The paper contains numerous equilibrium diagrams for various ferro-nickel alloys, also it includes charts showing the thermo-critical points of specific steels and the mechanical properties of the steels. This paper will be of considerable interest to those studying nickel and nickel alloys.

VERY PURE ALLOYS OF ELECTROLYTIC IRON, CARBON AND MANGANESE. By Robert E. Neville and John R. Cain, Associate Chemist and Research Associate respectively U. S. Bureau of Standards, in *Raw Materials*, November, 1922.

This paper describes the preparation and the mechanical properties of an extensive series of electrolytic-iron, carbon and manganese. The specific effect on pure iron of additions of manganese, additions of carbon and additions of carbon and manganese are thoroughly described.

POWER PLANT COST OF OPERATING HAMMERS. By R. E. Waldron in *Forging and Heat Treating*, October, 1922.

For economical hammer operation the unit must be in a good state of repair and adjustment, the evaporation rate from boilers must be as high as is possible, and least amount of coal possible should be used in getting boilers into operation. The paper discusses the steam consumption per hour for various sized hammers.

FORGING FURNACE CONSTRUCTION. By H. Johnson in *Forging and Heat Treating*. October, 1922.

The results of tests emphasizing the necessity of sufficient combustion space and the value of insulating brick are discussed. The reverberatory flame, proper oil temperature and atomization are important points brought out in the paper. Sufficient free air to complete combustion is vital.

TECHNICAL CONTROL OF THE McCOOK FIELD FOUNDRY. By E. H. Dix, Jr., in the *Metal Trade*. November, 1922.

This paper points out the advantages that have been obtained through the system of control of the foundry for making aircraft castings. A close check is kept on melting equipment, temperature control, casting temperatures, physical properties of castings, metallographic examinations and finally the correlation of tests and data.

FIRECLAY REFRACTORIES. By Alan G. Wikoff, in *Chemical and Metallurgical Engineering*. Nov. 15, 1922.

This paper outlines the manufacturing operations at the Laclede-Christy Clay Products Co., of St. Louis. Dry press and stiff mud process fireclay brick are discussed. The manufacture of special shapes, glass house refractories and washed pot clay are reviewed.

BURNING LIQUID FUEL IN FURNACES. By R. C. Helm, in *Iron Trade Review*. Nov. 9, 1922.

Fuel oil and tar have gained considerable favor in metallurgical operations during recent years. Many types of burners designed including those for open hearths are described. Principles of combustion are also discussed.

STEELS FOR AUTOMOBILE CONSTRUCTION. By Benno R. Dierfeld, in *Iron Age*. Nov. 9, 1922.

The author reviews the standardized steel specifications in vogue in the German automotive industry, pointing out what the various symbols and designations mean.

HEATING FURNACES FOR BLOOMS, SLABS AND BILLETS. By W. P. Chandler, Jr., in *Iron Age*.

A discussion of the two main types of furnaces for heating blooms and billets. Considerable data is given in which the results of tests show greater efficiency of the continuous recuperative type than in the regenerative furnace.

PRESENT STATUS OF THE ELECTRIC FURNACE IN REFINING IRON AND STEEL. By John A. Mathews in *Chemical and Metallurgical Engineering*. Nov. 1, 1922.

A brief review of the developments in steel making methods leading up to the electric furnace development. The flexibility of the electric furnace and the quality of its output has established its sound position. As consumers realize the importance and economy of using clean steel a greater demand for increased electric furnace tonnage is at hand.

THE PROPERTIES OF COLD-WORKED METALS. By Zay Jeffries and R. S. Archer in *Chemical and Metallurgical Engineering*. Nov. 1, 1922.

The authors explain the properties of cold-worked metals by a series of postulates regarding conditions at slip planes. The general theory has been checked by experiments on copper, nickel, iron, molybdenum and tungsten.

Reviews of Recent Patents

1,418,984. Electric Furnace. Frederick W. Sperr, Jr., and Harold J. Rose, of Pittsburgh, Pennsylvania, assignors to the Koppers Company, of Pittsburgh, Pennsylvania, a corporation of Pennsylvania.

The present invention relates to furnaces, and more particularly to electric furnaces for testing materials. The present invention is illustrated as embodied in an electric furnace for heating coal samples.

The object of the invention is to produce a furnace of this character in which the heating can be accurately and readily controlled. The furnace is so constructed that when used for heating a tube containing a coal sample, the sample may be heated progressively in such a way as to closely simulate the coking conditions of a byproduct coke oven.

1,420,980. Process of Manufacturing Electrical Resistance Material. Ferdinand Eichenberger, Aarau, Switzerland, assignor to the firm S. A. Kummler & Matter, Aarau, Switzerland.

The invention relates to a new and improved process of manufacturing electrical resistance material which stands low, intermediate and high temperatures.

The novel process consists in that silicon carbide is used as a base to which calcium carbonate, oxide of metals and graphite are mixed to vary the coefficient of resistance.

1,421,205. Work Holding and Feeding Device for Grinding or Polishing Machines. Rufus W. Fuller, Deerfield, Mass., assignor to Production Machine Co., Greenfield, Mass., a corporation of Massachusetts.

The invention relates to machines for grinding or polishing articles of cylindrical form, and more particularly to work holding and feeding devices for such machines.

1,421,429. Air-circulating system for industrial ovens. William C. Ehmka, Detroit, Mich., assignor to Detroit Sheet Metal Works, Detroit, Mich.

An oven in combination with an air heating apparatus, a circulating system, a circulating fan, an exhaust fan, means for operating same, upper and lower exhaust chambers, an intake pipe connecting the circulating fan with the upper exhaust chamber of the oven, a separate air intake breather also connected with the circulating fan intake, mean for regulating the proportions of hot air from the exhaust chamber to the fresh air from the intake breather as it enters the fan, and means for distributing same through the oven, and means for exhausting the air from the oven through the exhaust fan.

1,422,019. Alloy of Refractory Metals and Process of Forming Same. John Adam Yunck, South Orange, N. J.

This invention relates to an alloy of tungsten and thorium particularly useful in making metal filaments and incandescent lamps, and a method of making same. Various alloys of the refractory metals have been proposed for this purpose

because the alloys are usually more ductile than their constituents taken separately, but none of such alloys heretofore proposed have been successful for the purpose because they either had too low a fusing point, or volatilized at high temperatures and discolored the lamp bulb.

1,422,096. Alloy containing iron, nickel, chromium. Pierre Girin, Paris, France, assignor to Societe Anonyme de Commentry Fourchambault & Decazeville, Paris, France.

An alloy of iron, nickel, chromium and manganese, containing nickel, 20 to 25 per cent, chromium, 10 to 15 per cent, manganese, 1 to 2 per cent, carbon, 0.2 to 0.5 per cent, such alloy having, together with the mechanical qualities of the best steels, a high resistance to attack by strong acids, organic acids and alkalis, in solution or in fusion.

1,422,672. Thermocouple. Thomas G. Goghlan, Wellsburg, W. Va.

A thermo-couple comprising different metals forming a union and means comprisinb an open chamber for housing said union so as to permit its exposure to heat transfer from gaseous products of combustion and prevent its ignition of an unexploded fluid adapted for providing such gaseous products.

1,422,710. Process of annealing malleable cast iron. Charles T. Holcroft, Detroit, Mich.

The method of annealing malleable iron castings which consists in exposing the material to temperatures variable in a definite progression, such progression being effective to raise the temperature of the material at a rate proportionate to the thermal conductivity to a predetermined point of reaction, to maintain reaction temperature for a predetermined time, and then to lower the temperature to a point below which rapid cooling will not injuriously affect the material.

1,423,022. Oil Burner. Austin A. Riley, Indianapolis, Ind., assignor of two-thirds to Central States Bridge Co., Indianapolis, Ind., a corporation of Indiana.

The object of this invention is to provide an oil burner in which air to effect complete combustion is provided in quantities regulated to suit the supply of oil, and in a manner to thoroughly nebulize the oil in a chamber provided within the nozzle, before discharge for ignition.

1,423,128. Sand-Blast Apparatus. Hugo F. Liedtke, Hagerstown, Md., assignor to Pangborn Corp., Hagerstown, Md., a corporation of Maryland.

This invention relates to sand-blast apparatus for cleaning castings or like purposes, of the type in which a sand-blast nozzle is movably mounted in a chamber or cabinet into which the castings or articles to be treated by the sand blast are transported by a movable carrier which also effects their delivery from the sand-blast chamber.

1,423,338. Alloy and the Method of Producing Same. Clemens A. Laise, Weehawken, N. J., assignor by Mesne Assignments, to General Electric Co., Schenectady, N. Y., a corporation of New York.

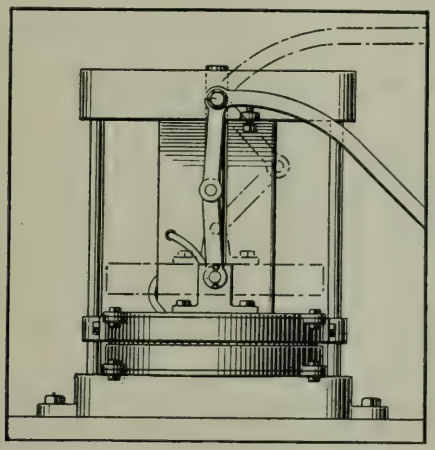
This invention relates to a new and useful alloy and to the method of producing the same. It relates more particularly to the production of an alloy that shall possess desirable properties which make it especially suitable for uses as electrical

contacts, magneto points, targets and sheet metal for wireless equipment, and wire for heating and lighting elements. It includes gold, tungsten, calcium vanadate and thorium oxide.

A. J. Harry, 1315 East 143rd Street, Cleveland.

A member of the American Society for Steel Treating has recently patented a new press which in addition to providing the necessary heat treatment to saws and flat tools, exerts sufficient pressure on the work to prevent its warping after removal from the press. A view of this electrically heated press for saws and flat tools is shown in the accompanying sketch.

The device consists of a base plate and a movable top plate which is raised and lowered by means of a handle and crank arm. Both plates are heated electrically by means of coils placed inside, the temperature being indicated by a thermocouple.



High-speed steel articles such as disk saws usually are treated in a furnace to a temperature of 2250 degrees Fahr., after which they are quenched by being subjected to a lower temperature about 1150 degrees Fahr. This scond step is accomplished by quenching the tools into an oil bath at room temperature, after which they are drawn at 1150 degrees Fahr.

With the new machine the saws are removed from the furnace and placed between the plates and subjected to pressure, the heating elements being operated at the same time to cool the work down from 2250 degrees Fahr. to 1150 degrees Fahr., or the red hardness point. It is claimed that the saws are maintained straight and the mechanical and structural conditions are such that no further heat treatment is required.

News of the Chapters

SCHEDULED REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Boston—Second Tuesday
Bridgeport—Thursday between 20th and end of month
Chicago—Second Thursday
Cincinnati—Second Thursday
Cleveland—Fourth Friday, Cleveland Engineering Society Rooms, Hotel Winton; meeting at 8:00 p. m.
Detroit—Second and fourth Monday. For meeting place call W. G. Calkins, Secy. Detroit Twist Drill Co.
Hartford—Friday nearest 10th of month
Indianapolis—Second Monday
Lehigh Valley—No regular night
New Haven—Third Friday
New York—Third Wednesday
Philadelphia—Last Friday
Pittsburgh—First Tuesday
Providence—No regular night. Nov. 10th, Dec. 12th.
Schenectady—Third Tuesday
Springfield—Third Friday
South Bend—Second Wednesday
St. Louis—Third Monday
Syracuse—No regular night
Tri City—Thursday
Washington—Third Friday
Rockford—Second Friday following the second Thursday

STANDING OF THE CHAPTERS

New members amounting to 156 were added during the month of October as compared with 45 new members during September. The large number of new members is indeed an excellent showing, but it must be borne in mind that probably half of the new members were secured at the convention at Detroit, and it does not necessarily portray extended activities on the part of the chapters, with the possible exception of Detroit.

It is also interesting to note that the largest chapter in the American Society for Steel Treating at the present time is the Detroit Chapter. This is the first time that Chicago has ever been out of the lead, and much credit is due to the Detroit Chapter under the leadership of membership chairman W. E. Blythe for the excellent showing.

The following explanation will be of assistance. The chapters shown in capitals have advanced their position from that occupied in the previous report. Those shown in italics are not occupying as high a position as

in the previous report. Those printed in regular type, (ie, Pittsburgh and Philadelphia) are occupying the same position as in the previous reports.

The standing is as follows:

1. DETROIT
2. *Chicago*
3. Pittsburgh
4. Philadelphia
5. Cleveland
6. New York
7. Hartford
8. Milwaukee
9. Boston
10. Lehigh Valley
11. SYRACUSE
12. WORCESTER
13. *Indianapolis*
14. NORTH WEST
15. *Rockford*
16. **Cincinnati*
17. *SPRINGFIELD
18. **Washington*
19. *Tri City
20. Providence
21. *BUFFALO
22. *SCHENECTADY
23. ST. LOUIS
24. *New Haven*
25. SOUTH BEND
26. *Toronto*
27. Rochester
28. Bridgeport

*Tied

BOSTON CHAPTER

One hundred and forty members and guests of the Boston chapter gathered at the plant of the Consolidated Gas Company in order to be present at the regular November meeting. The first part of the evening was turned over to the presentation of a six-reel moving picture showing "The Story of the Automobile." The picture was very well received. The second portion of the program was the explanation by Mr. W. W. Cummings, Industrial Engineer for the Boston Consolidated Gas Co., of the manufacture of gas.

A miniature plant in actual operation was prepared so those present were able to follow each individual step in the manufacture of gas, even a miniature house was shown in which the gas being produced by the miniature plant was used.

National President, T. D. Lynch, Second Vice President, W. S. Bidle, and National Secretary W. H. Eisenman were present at the meeting and extended the greetings of the National Society to the membership. At the close of the meeting a buffet luncheon was served by the Gas Company, and everyone agreed that the evening had been a most profitable and enjoyable one.

This is the third of a series of meetings held by the Boston chapter in local plants, where actual demonstration of various heat treating equipment is shown, and where things are accomplished under actual working conditions.

The next meeting will be held in the laboratories of the Massachusetts Institute of Technology.

CHICAGO CHAPTER

The Chicago chapter held its November meeting Thursday evening, Nov. 9 at 8 p. m. in the Chicago City club rooms, Plymouth Court and Jackson boulevard.

H. J. French, physicist of the United States Bureau of Standards was

the speaker of the evening. He presented a very interesting paper entitled "Some Factors Affecting the Heat Treatment of Steel."

Mr. French, who has had wide experience in heat treatment and study of the properties of steels and alloys, delivered a very interesting talk, which was instructive and very valuable to all who were there.

Following Mr. French's paper a lengthy and interesting discussion ensued. This meeting proved to be one of the best of the year, as evidenced by the large turn out.

CINCINNATI CHAPTER

The Cincinnati chapter of the American Society for Steel Treating held a joint meeting on Nov. 16, at 8 p. m. in the Literary club rooms, 25 E. 8th street, Cincinnati, O. The speaker for this meeting was R. H. Sweetser, Assistant to the Vice President of the American Rolling Mill Co., Columbus, O., who discussed very fully the "Making of Pig Iron."

Mr. Sweetser was particularly well fitted to tell the story of pig iron, as in addition to his connection with the American Rolling Mill company he is president of the Southern Pig Iron & Coke association and is vice president of the Portsmouth By-Product Coke company.

Mr. Sweetser's talk was illustrated by a moving picture firm showing a modern blast furnace in operation.

The meeting was well attended and proved to be a very entertaining and instructive talk.

CLEVELAND CHAPTER

The Cleveland chapter of the society held its November meeting on Tuesday evening the 21st. This meeting was a joint meeting with the American Institute of Mining and Metallurgical Engineers, the Cleveland Engineering Society and the American Society of Mechanical Engineers.

The speaker for this meeting was Dr. J. A. Mathews, president of the Crucible Steel Co. of America, who presented a very capable and interesting paper entitled "Alloy Tool Steels." Dr. Mathews holds an unique position in the industrial world. He is an eminent metallurgist, having contributed very largely to the development of alloy steels during his experimental and research days and now he holds the position as chief executive of one of the large steel companies of this country.

Dr. Mathews presented some very interesting information relative to alloy tool steels. Following this paper an interesting and comprehensive discussion was held.

About 200 members and guests were present.

DETROIT CHAPTER

The November 13th bimonthly meeting of the Detroit Chapter was very well attended. Well over a hundred members were present to hear Mr. E. G. Steadman of the Timken Roller Bearing Co., Canton, O., plant, who read a paper on Electric Furnace Melting Practice. He presented the subject

from the standpoint of the furnace operator, from the preparation of the charges to the rolling into blooms. Lively discussion followed the reading of his paper.

HARTFORD CHAPTER

The Hartford chapter held its regular monthly meeting Friday, Nov. 17 in the assembly hall, Hartford Electric Light Co., Pearl street, Hartford, Conn.

Major A. E. Bellis, the speaker of the evening, presented an interesting paper entitled "Salt Baths for Heat Treating." Major Bellis, formerly of the Springfield Arsenal and now head of the Bellis Heat Treating Co., New Haven, has had wide experience in the development and application of mixtures of salts suitable for use as heating mediums in the heat treatment of steel. Major Bellis discussed the requirements of salt baths for treating carbon and alloy steels, and showed to what extent the salt bath is now used to meet these requirements. Specimens of hardened tools and parts were exhibited to illustrate the advantages and possibilities of the salt bath method of hardening.

By special arrangements with the Hartford Electric Light company and the General Electric company, several types of electric furnaces, ovens and drawing baths were on exhibition in the hall. These instruments were in operation and were demonstrated by a representative of the General Electric company.

INDIANAPOLIS CHAPTER

The regular monthly meeting of Indianapolis Chapter was held the evening of the 13th at the Hoosier Athletic Club. The meeting was held following a dinner. Dinner meetings have not been held by the Chapter for some time, this being the first in over a year. There were ninety-six present at dinner, making it the biggest meeting on record for this chapter.

The meeting was opened at 8:15 and a paper was presented by Mr. H. E. Hayward, Metallurgist of the Link-Belt Co., of this city. Mr. Hayward's paper was entitled "Practical Applications of Metallography." Mr. Hayward had spent considerable time in preparing his subject and selecting slides to illustrate his paper. A microscope was at hand and after the presentation of the paper, Mr. Hayward exhibited interesting specimens of steels treated to give various conditions.

Following the paper, discussion was held in connection with the proposed course in Heat Treatment, that is being organized by Indianapolis Chapter. Prof. John Keller of Purdue University was at hand and told us of the Purdue Extension service and how the Chapter could obtain his assistance in helping us carry out the plan of the course.

Many representatives of various concerns around the city were present at the meeting and over thirty signified their intentions to enroll in the proposed course. At the present time, the date of the opening of the

course has not been definitely decided but it is thought that it will probably not begin before the first of January.

SOUTH BEND CHAPTER

The South Bend chapter held a meeting on Nov. 8, at the Studebaker Cafeteria, plant No. 2. This meeting was in the form of a smoker. Seventy-one guests were present. S. M. Havens, National Director, spoke in general and in detail regarding the National Society and its relationship to the chapters.

Mr. Havens' talk was very well received, and proved of much interest, and it is believed will result in much good for both the chapter and the National Society.

Following Mr. Havens' talk, W. J. Harris, a member of the South Bend chapter read a paper entitled "Some Phases of the Machinability of Steel."

This paper was well received and very interesting. The discussion on this paper will be held at the next meeting in December.

Professor Keller of Purdue university was the main speaker for this meeting, and delivered a very interesting lecture entitled "Why Steel Warps." He illustrated his paper very ably and interestingly by the use of charts and diagrams. Professor Keller's paper proved of great interest to all present, as he is an authority on the heat treatment of steel.

MILWAUKEE CHAPTER

The Milwaukee chapter held a meeting Monday evening, Nov. 6, 1922, 8 p. m. at the Blatz hotel. The red invitation cards, which the secretary had sent out announcing this meeting did some very good work, as it brought out 53 guests to dine with Mr. Havens and Mr. MacKenzie.

Following the dinner, which was served at 6:45 p. m. about 90 members and guests came in to attend the lecture and moving picture exhibition depicting the manner in which alloy steels are made at the plant of the Interstate Iron & Steel Co.

Mr. W. J. MacKenzie of the Interstate Iron & Steel Co. lectured during the exhibition of the moving picture films.

Mr. S. M. Havens addressed the assembly on matters pertaining to the National Society as well to the local chapter.

We are glad to note that the Milwaukee chapter members are showing such a fine spirit of co-operation, and it is only through such co-operation that the aim of our society can be realized to the utmost.

NEW HAVEN CHAPTER

Mr. R. J. Allen of the Rolls Royce Company of America, Springfield, Mass., and first Vice President of the American Society for Steel Treating, addressed the members of the Society Friday evening, Nov. 17th. Mr. Allen spoke very interestingly and entertainingly on the subject of the Testing of Steel. And the presentation of this paper brought out many valuable points.

Following the meeting an election of officers was held with the following results:

Chairman: Major Reuben A. Hill, First Vice-President, and Secretary Marlin Fire Arms Corporation, New Haven, Conn.

Vice-Chairman: Professor C. H. Mathewson, Professor of Metallurgy, Yale Scientific School, New Haven, Conn.

MAJOR REUBEN A. HILL
Chairman of the New Haven Chapter

Secretary and Treasurer: Mr. Walter G. Aurand, Chief Chemist, R. Wallace & Sons Mfg. Co., Wallingford, Conn.

The New Haven Chapter is quite sure that the activities of the chapter for the coming year will be well taken care of with such a capable list of officers.

NEW YORK CHAPTER

About 75 members gathered at the Machinery Club, 50 Church St., in order to attend the regular November meeting and to hear a paper presented by L. H. Fry, Metallurgist of the Standard Steel Car Company, Burnham, Pa., on the subject of Hammered and Pressed Forgings.

Mr. Fry handled his subject in an exceptionally capable manner, showing the various stages through which the large forgings produced by his firm must be taken. Mr. Fry pointed out particularly that the principal concern in producing of a proper forging was involved in the proper making of

the steel. He compared the result obtained by hammer forging and also the result obtained by pressing, pointing out the advantages and disadvantages of each method.

A very interesting discussion took place at the close of Mr. Fry's paper, in which a large number of the members participated.

National President, T. D. Lynch, Second Vice President, W. S. Bidle and National Secretary, W. H. Eisenman, were in attendance at the meeting and extended greetings to the chapter.

NORTH-WEST WEST CHAPTER

The first meeting of the North-West West chapter of the society was held Nov. 15 in the club rooms of the Manufacturers Club, Builders Exchange building, Minneapolis.

This meeting was devoted to a technical subject, presented by E. C. Smith, metallurgical engineer, with the Central Steel Co., Massillon, O., who spoke on the subject of "Steel Used in Automotive construction."

Mr. Smith's subject covered forging stock, sheets and strips and was well illustrated with stereopticon slides, showing the manufacture of these materials.

Mr. Smith presented his subject in a very capable manner, as was evidenced by the large amount of interesting discussion which followed his paper. It was well received and an interest to all those who were in attendance.

PHILADELPHIA CHAPTER

The regular meeting of the Philadelphia Chapter was held at the Engineers Club on Spruce St., Friday evening, Nov. 24th. The program was arranged especially for the Student members of the Chapter and included a motion picture, giving the phases in modern Steel Manufacture. These pictures were shown through the courtesy of the Midvale-Cambria Steel Co., and were explained by Mr. George A. Richardson. The pictures were only recently released and were of very remarkable value. They showed the process of the manufacture from the ore to the finished produce.

In addition to the moving picture, there was a practical lecture by Dr. Walter M. Mitchell, Consulting Metallurgist of Philadelphia, and a member of the Executive Committee of the local chapter. Dr. Mitchell's subject was "The Heat Treatment of Steel, its Purpose and What It Accomplishes." Dr. Mitchell has the rare faculty of being able to lecture in such a way that intricate problems were rendered very simple. He prepared his talk so that it would explain to the students some of the very fascinating and important phases of steel treating, which are necessary in order that the fullest benefits may be obtained.

President T. D. Lynch was present at the meeting, and extended a message to the local chapter from the National Society.

PITTSBURGH CHAPTER

Tuesday evening, Nov. 7, the Pittsburgh chapter of the American Society for Steel Treating held its regular monthly meeting in the

main dining room of the Hotel Chatham. Some 75 members were present for dinner to hear the report of J. V. Emmons, National treasurer of the society.

Following Mr. Emmons' talk William J. Priestly, formerly of the United States Naval Ordnance plant at Charleston, West Virginia, presented an illustrated paper covering in an informal way the manner in which operations were conducted in the manufacture of large shells, armor plate and gun forgings. He pointed out that the particular feature of interest of this plant was the manner in which they duplexed their steel. The steel is first refined in a 75 to 90-ton open hearth furnace and from there transferred by means of ladles to two 55-ton capacity electric steel furnaces which remove the sulphur, oxides and the last of the impurities in the steel. The steel is then cast into fluted ingots for manufacture of the large shells and gun parts and into comparatively wide thin ingots for armor plate.

Mr. Priestly pointed out that they found in their practice that a top cast ingot with a hot top, with the taper running from top to bottom, being wider at the top than at the bottom, proved most satisfactory. The fluted ingots did not contain as pronounced curves as is usually the case, and were regarded by Mr. Priestly as far superior to the usual fluted type.

The heavier ingots were forged under a press some idea of whose gigantic size may be gained from the fact that the columns were 30 inches in diameter. A four or five-inch hole was drilled through the entire length of these columns to make certain that they were of sound steel. Recuperative producer-gas furnaces of the car type were used in heating for forging and in heat treating these unwieldy masses of steel. Mr. Priestly mentioned the fact that the troublesome snowflakes were avoided at this plant by careful practice in pouring at the correct temperature and in forging and heating.

This plant has been closed down since the limitation of armament conference.

In closing Mr. Priestly gave as his opinion that electric steel is not necessary in most commercial work for open hearth steel can be made on a quality and quantity basis to meet most requirements of the present day.

The members greatly enjoyed the entertainment provided by Misses Braumers and Langestras and the old fashioned singing school which they inaugurated.

RHODE ISLAND CHAPTER

The Rhode Island Chapter of the A. S. S. T. held their regular November meeting at the Engineers' Club, Friday, November 10th. The principal address of the evening was presented by Mr. J. N. Voltmann of the W. S. Rockwell Co., New York City. Mr. Voltmann is an authority on furnaces and dealt with his subject in a very interesting manner. His talk was illustrated by lantern slides, showing the various types of furnaces best suited for production in different manufacturing progress.

National Secretary W. H. Eisenman spoke to the members with reference to the activities and services of the National Society. About 75 were in attendance.

Owing to ill health, Mr. R. H. Schaefer, Chairman of the Rhode Is-

land Chapter found it necessary to resign, and the Chairmanship has been assumed by Mr. F. H. Franklin, Consulting Chemist, 184 Whittier Ave., Providence, R. I., who was the Vice Chairman.

ROCKFORD CHAPTER

The first regular meeting of the season was held October 27th at the Nelson Hotel. Mr. R. G. Guthrie speaking on "Application of Gas in Heat-Treating.—Equipment and Appliances." Mr. Guthrie's lecture was received with much favor. The demands he made for a modern heat treating plant were rather a novelty, but appeared reasonable after he went into details. He pointed out that furnaces should not be considered as merely furnaces, but should be rated with machine tools and therefore deserve to be called heating machines. Mr. Guthrie stated that the laws of radiation are violated in heat treating plants, the color of most heating apparatus being black, instead of white, as it should be. He criticized further the prevailing tendency of insufficient lighting and ventilation, and all together his most interesting paper gave food for much thought, as was proven later on by a lively discussion of the subject. Mr. Guthrie earned everlasting gratitude with the members of the Rockford Chapter, and in a following directors meeting it was decided to ask him to lecture again in the near future.

On November 2nd. about 30 members and guests of the Chapter followed an invitation of the Fairbanks-Morse Company, Beloit, Wisconsin. Under Mr. Chas. Cotta and Mr. H. G. Higgins approved leadership, the delegation got under way in 7 cars furnished by members of the Chapter and arrived in Beloit in good time and without mishap, where officials of the plant received them most cordially and where guides were provided to take the groups to different departments and furnish any information desired. The main feature of the excursion was the huge foundry recently established and working in full swing. This foundry is without doubt the most up-to-date in the middle west. The forge shop was another point of interest. Crank shafts and other forgings of large size being handled with apparent ease. The delegation left the plant late in the afternoon, thoroughly satisfied that the time was well spent. It was unofficially decided then and there that excursions of a similar kind should be arranged at more regular intervals.

At the meeting of November 10th Mr. H. J. French, of the Bureau of Standards, Washington, D. C., spoke on "Some Factors Affecting the Heat Treatment of Steel." His lecture was illustrated by numerous slides. The discussion following Mr. French's paper held members and guests together till 11 P. M. This meeting being especially well attended was one of the most successful ever held by the Rockford Chapter.

Mr. O. H. Olson's resignation as Vice-Chairman was read and accepted with much regret. The members were also informed of the pending attendance and membership contest. There were present a number of out of town guests, and also a number of applications for membership received.

THE SCHENECTADY CHAPTER

A special meeting was held by the Schenectady chapter on the afternoon and evening of Thursday, Nov. 9. About twenty members and guests attended this meeting, among whom was W. H. Eisenman, national secretary of the society. All of those that attended, visited

the plant of the Ludlum Steel company at Watervliet, N. Y., where a profitable and enjoyable time was had.

Mr. P. A. E. Armstrong gave a very interesting talk on "Stainless Steel." Following Mr. Armstrong's talk the Ludlum Steel company entertained those in attendance at a dinner.

Jim Cran and Bill Eisenman kept the crowd amused by their good stories and humorous anecdotes.

Mr. Eisenman was presented with a hand made ash tray by his good friend Jim Cran.

At eight o'clock a business meeting was held at the Rensslaer Polytechnic Institute. Mr. A. C. Cooley addressed the chapter on the "Manufacture and Physical Properties of the Metal Tungsten."

While this paper dealt with a subject that was not exactly a steel treater's subject, the talk was extremely interesting, because of the similarity which exists between the metal tungsten and steel, as well as the peculiar differences which occur in the working of these two materials.

A large number of questions during and following the talk was a measure of the keen interest in this paper.

About fifty members and guests were present during the evening meeting.

SPRINGFIELD CHAPTER

The Springfield Chapter deviated from its usual program and held their November meeting on Friday, the 17th at the Fitzgerald Forging and Heat Treating Company's plant on St. James Avenue, Springfield. Mr. Z. L. Sault, President of the New England Annealing and Tool Company of Boston was present and presented the principal talk of the evening. Mr. Sault not only gave a practical talk but he also demonstrated the heat treatment of steel.

Mr. Sault has had many years experience in the actual hardening of tools and dies, and is one of the very few men who accompanies his talk with an actual demonstration of heat treating.

The Fitzgerald Company was a very pleasant host and had both carbon and high-speed furnaces in operation. The meeting was well attended, about 75 showing their willingness to see the latest methods properly demonstrated.

Mr. W. D. Fuller, Mgr., of the New England Heat Treating Service Company was present and gave a demonstration of the Rockwell Hardness Tester.

Mr. W. H. Eisenman, National Secretary, was present at the meeting, and renewed acquaintanceship with the members of the Chapter and their guests.

ST. LOUIS CHAPTER

The St. Louis chapter of the society held its regular monthly meeting Monday evening, Nov. 20, 1922 at the Annex hotel, Sixth and Market streets.

The meeting was preceded by the usual get-together dinner, which was served at 7 p. m.

Following the usual order of business, the speaker of the evening,

George W. White of the DeRemer-Blatchford Co., Chicago, Ill., presented his paper entitled "Furnaces, Construction and Uses."

Mr. White presented his paper in a very capable manner and brought out very many valuable points in the matter of design of furnaces for a uniform heat treatment.

Many questions and much interesting discussion followed the presentation of this paper.

SYRACUSE CHAPTER

An interesting meeting was held by the Syracuse chapter Nov. 10 at 8 p. m. in the rooms of the Chamber of Commerce, 433 South Warren street, Syracuse, N. Y.

J. D. Cutter, vice president and metallurgist of the Climax Molybdenum company delivered a very capable paper entitled "Molybdenum Steel."

As molybdenum steel has had the lime-light for some time past, Mr. Cutter's paper proved to be very interesting and attractive to the members of the Syracuse chapter, as evidenced by the very good turnout which they had.

WORCESTER CHAPTER

The November meeting of the Worcester chapter was held Thursday evening, the 16th at which time Mr. J. P. Gill, metallurgist of the Vanadium-Alloys Steel company presented his very capable paper entitled "High-Speed Steel from a Practical Standpoint."

Mr. Gill has had wide experience on the manufacture of high-speed steel and spoke with authority on this subject.

Following Mr. Gill's paper a very interesting discussion ensued.

The meeting was very well attended and proved interesting to all.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A repesents Associate Member; S represents Sustaining Member; J represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

NEW MEMBERS

AAMODT, M. H. G., (M-10) 103 E. 16th St., Minneapolis, Minn.
AMES, W., (M-11), B. C. Ames Co., Waltham, Mass.
ANDERSON, A. J., (M-10), 1303 Monroe St., N. E., Minneapolis, Minn.

CLIMAX MOLYBDENUM COMPANY, (S-11) 61 Broadway, New York City.
CRESSMAN, H. E., (S-10), E. F. Houghton & Co., 1002 Beaufait, Detroit, Mich.

DANZIGER, E. H., (Sb-10), 17 Madison Ave., New York City.
DIBBLE, B. F., (M-10), 303 3rd St., So., Minneapolis, Minn.
DUMAS, M. G., (M-9), 1708 135th St., E. Chicago, Indiana.

GRIFFITH, J. R., (M-11), 934 N. 8th St., Philadelphia, Pa.

HANCOCK, GEO. M., Union Charcoal Chemical Co., Olean, N. Y.
HARMAN, W. H., (S-11), Southwork Fdry. & Mach. Co., 4th and Washington Avenue, Philadelphia, Pa.
HAY, T. N., (A-10), British America Nickel Corp., Ltd., Ottowa, Ont., Can.
HIGGINS, HARRY J., (M-11), 223 Dale St., Waltham, Mass.
HILL, RUEBEN, (M-11), The Marlin Firearms Corp., New Haven. Conn.
HYSLOP, THOS. B., (M-10), 9190 Livernois Ave., Detroit, Mich.

JERRY, H. J., (M-11), 235 Union St., Schnectady, N. Y.
JONES, A. ARTHUR, (M-11), 1810 Jefferson Ave., Philadelphia, Pa.

KLOPSCH, OTTO Z., (M-11), 3250 Highland Pl., Washington, D. C.
KNIGHT, A. L., (A-10) 905, Ogden Ave., Toledo, O.
KRAFT, A. N., (M-11), 41 Mallery Pl., Wilkes Barre, Pa.

LEDIN, THEO. A., (M-9), 71 Gladstone Ave., Detroit, Mich.
LARENZ, F. A., JR., (M-9), Amer. Steel Foundries, Indiana Harbor, Indiana.
LOWE, RUSSELL, (M-11), 147 Varick St., New York City.

MALABY, V. R., (M-11), 5605 Haverford Ave., West Philadelphia, Pa.
MARTIN, H. T., (S-11), Lanston Monotype Mach. Co., 24th & Locust St., Philadelphia, Pa.
McMANNUS, W. H., (M-10), 50 Peterboro St., Detroit, Mich.
MORRMANN, THOS. A., (M-11), 1425 Cedar St., Milwaukee, Wis.

RAINE, C. R., (M-10), Ridge Rd. and Dayton St., Pleasant Ridge, Royal Oak, Michigan.
REINHARDT, G. A., (M-10), Youngstown Sheet & Tube Co., Youngstown, O.
ROBINSON, J. E., (M-11), 1421 Cedar St., Milwaukee, Wis.
RUSSELL, L. S., (A-10), 714 Wisconsin Ave., Oak Park, Ill.

SEARLE, W. C., (M-10), Reed & Prince Mfg. Co., Worcester, Mass.

SHERMAN, D. E., (M-11), 2153 Temple Ct St., St. Paul, Minn.
STEVENSON, WM., (M-10), 1496 Collingwood Ave., Detroit, Mich.
SPRING, L. W., (M-11), 836 So. Michigan Ave., Chicago, Ill.
SPURRELL, S. S., (M-11), 1205 Bemet St., Lansing, Mich.
SWEDISH CRUCIBLE STEEL CO., Detroit, Mich., (S-11).

TOBIN, C. J., (M-10), 2235 Highland Ave., Detroit, Mich.

UPTHEGROVE, CLAIR, (M-10), 125 Chemistry Bldg., Ann Arbor, Mich.

VAUGHN, Howard A., (S-11), 2114 Carroll Ave., Chicago, Ill.

WOODWARD, R. W., (M-11), The Whitney Mfg. Co., Hartford, Conn.
WILBER, C. L., (M-10), Timken Detroit Axle Co., 136 Clark Ave., Detroit, Mich.

CHANGES OF ADDRESS

CLARK, LORENZO T., from 5793 Kingsbury Pl., St. Louis, Mo., to Leschen Wire Rope Co., St. Louis, Mo.

FOWLER, H. R., from 43 Roughley Rd., Arlington, Mass., to 42 Orchard St., Cambridge, Mass.
FREDERICK, J. B., from 425 Oakley Ave., Rockford, Ill., to 2203 Auburn St., Rockford, Ill.

GLEISSINGER, H. C., from 6337 Charlevoix Ave., Detroit, Mich., to 2999 Bellevue Ave., Detroit, Mich.
GRIGGS, H. L., from 139 E. 66th St., New York City, to Room 1002 Engineering Bldg., 114 Liberty St., New York City.

HARDEN, ALAN F., from 59 Sherman St., Springfield, Mass., to P. O. Box 584, Springfield, Mass.
HINER, W. F., from 15200 Turlington Ave., Harvey, Ill., to 15626 Myrtle Ave., Harvey, Ill.
HUNNINGS, S. V., from 2826 27th St., Washington, D. C., to Weldless Rolled Ring Co., 10022 Detroit Ave., Cleveland, Ohio.

JENNINGS, F. H., from Fox Motor Co. to Engineering Tool Corp., Philadelphia, Pa.

LEKBERG, C. H., from 9814 Ave. H to 10639 Ave. F, Chicago, Ill.

MARBLE, W. H., from 5915 Sturgeon St., Pittsburgh, Pa., to Jones & Laughlin Steel Co., Industrial Engr. Dept., Woodlawn, Pa.

QUADENFIELD, W. A., from Chrome Steel Works, Chrome, to 528 Poplar St., Roselle, N. J.

REEDER, E. R. S., from Ludlum Steel Co., 1008 Marine Trust Bldg., Buffalo, N. Y., to Wheelock Lovejoy Co., 128 Sidney St., Cambridge, Mass.
ROOT, H. H., from 259 Newbury St., Boston, Mass., to 146 Thirty-third St., Whitestone Landing, New York.

SULLIVAN, L. J., from 505 Fourth Ave., College Point, Long Island, N. Y., to 309 First St., Keyport, New Jersey.
SURTEES, R. E., from 2919 Anderdon, Detroit, Mich., to 4134 St. Jean Ave., Detroit, Mich.

WOENER, WM. J., from Rohr St., Rochester, N. Y., to 5 Lundy's Lane, Rochester, N. Y.

TRANSACTIONS

of the

American Society for Steel Treating

Vol. III Cleveland, January, 1923 No. 4

NINETEEN TWENTY-THREE

AS WE enter the threshhold of this New Year the Society extends its greetings to all members and expresses the hope that the record of achievements for the members and the Society will mark the greatest advancement in 1923 of any year. Each of us has an important work to do in 1923, and we will be judged by the records of our achievement. Each individual member has it within his power to contribute to the advancement of society. This part may be in any number of ways, either by increasing efficiency, thus increasing production or by investigating, and stopping avenues of waste that may be discovered. If this contribution for 1923 does not find expression in increased efficiency in your own department, it may find expression in contribution to the welfare of the steel treating fraternity. This possible contribution may be either by a paper presented before a Chapter, Sectional or National meeting or by a discussion of some interesting topic that may be instrumental in bringing valuable assistance to some member of the Society. In this way, you have not only been of great help to others, but you will also find much satisfaction in the thought that you have been of service. It may be that a portion of this service for 1923 may find expression as a member of some of the National Committee, or as a member of a local chapter committee. If that is the case, great energy applied to the accomplishment of the problems placed before you will contribute materially to the continued rapid and pronounced advancement of the Society.

It is a well recognized fact that the Society owes its members a service, and while a service has been given that is greater in scope and volume than even the oldest members might have hoped for, yet every effort will be extended to increase that service in 1923. The last two years have marked an advance in the accomplishments of the National Society, which is a point of just pride for all. Nevertheless, there is no reason for self-satisfaction, and we feel justified in stating that your Board of Directors will lend every effort in order that the Society may accomplish what it is intended should be accomplished, and that these accomplishments may be of great and inestimable value to its members.

The purpose of the A. S. S. T. is educational and not for profit, except that profit which means increased educational advancement of its members and for all of the users of steel. The A. S. S. T. is a co-operative institution. Co-operative in the sense that it is a joint working organization of all, with each classification having its special work to do, and the degree of energy with which this work is done will be the slide rule by which its percentage of accomplishments is measured.

So let us enter into 1923 with a steadfast purpose and maintain all

MEETING OF BOARD OF DIRECTORS OCT. 27, 1922

through the year the same spirit with which we begin. Let us all do the work that is assigned to us to the best of our ability, so that when 1923 closes its books we shall find entered upon the pages credit for having done the best within us. The future holds great possibilities for increased usefulness, and the manner in which we make use of the talents given us will be the degree by which success or failure will be measured.

Let it be Success.

MAKING A CHANGE

CLAUDE W. SUTTON, who at the age of 39 became president of a large concern in whose employ he had entered four years previous, writes very entertainingly and interestingly in the December *American* with reference to knowing when to leave a job, as well as when to take one. "An ambitious man" says Mr. Sutton, "will hold three or four, maybe a dozen, jobs, before he reaches one that exactly fits or which he can alter to fit. In fact, very rarely is a man under thirty serving his own best interests by holding on to one job, or even one kind of a job beyond a reasonable period. He needs contact with various kinds of organizations before he really knows what he is or what he wants. He can use these jobs to gain experience and not care at all about the good will. If he does not care about the good will, he makes every future step forward unnecessarily difficult. He has to bother about getting new jobs, instead of having them offered him. Then, when he gets placed, a crowd at once turns up to knock him."

The author in the article points out that a man who gets fired, or leaves, hardly ever misses an opportunity to get something off his mind. He thinks he is a poor weakling if he does not do something to help out his pride, but if the individual uses the proper amount of discretion, he will take particular care to see that he does not make any enemies upon leaving a position. It is an important item that the good will which an individual builds up in an organization should remain with the firm after he has taken his departure. No doubt a great number can recall really first class individuals who are out of work, yet who ought to be working, because their ability is considerably above the average. They are all men between forty and fifty, the age at which a man is always at his best. They are out of work solely because they have never left a job without a row. Not one of them ever left a job except with his head in the air with defiance sticking out all over him. Always, in the next job, a man works his fingers off to get the business of his former employer, and now people are afraid to hire them.

We are inclined to agree with Mr. Sutton in a great many of his statements. Yet there is a feeling common to all of antipathy toward changing satisfactory and congenial environments in an endeavor to find other lines of work that might be somewhat more pleasant. It is quite probable too that an individual thirty years of age is and should be happily married and consideration must be given to conditions best fitted to promote the interest of his family. The large majority of individuals are not of a roving disposition, but purchase property in the town where they are located, place their children in school; their family becomes acquainted and form friendships that requires more than a money consideration to destroy. Where the worth of an individual is properly recognized and working conditions are satisfactory, it is doubtful if all the advice contained in the article relative to changing to so many positions, is desirable of fulfillment.

ARE YOU A LIABILITY?

DURING the recent industrial depression it became necessary for a great many firms to curtail expenses. The rapidity with which they discontinued the services of men in their physical and chemical laboratories was surprising and alarming. It seemed that those in authority did not realize the real value to their organization of these departments and consequently had the least hesitancy in quickly disconnecting them from the payroll. One gathers the impression that the reason for this was due primarily to the men themselves, inasmuch as they probably had not taken an opportunity to prove to the management that the physical and chemical laboratories and metallurgical departments were an asset in place of a liability. It does not require a cost accountant to determine whether or not your department is making a profit. While you may be confident that your department is registering on the proper side of the ledger, nevertheless, it is always advisable to have it in actual figures and in black and white. Those in charge of a department should know the exact cost of each day's operation and within the fraction of a cent the exact cost of each individual operation. To do this might appear to be a large undertaking, but by an analysis of your department and a conference with the proper authority, the direct overhead charges can be readily ascertained, and the question of figuring your costs from day to day should involve a minimum amount of work and should be considered a necessary part of your activities.

Your company should know, and you should know that at your present salary they are getting back the money they pay you. They should realize that they are not only getting back the money they pay you, but they are making money on you. If you could prove to the company that they are making money on you, your future should be quite certain. If the company should wake up some day and prove that it is losing money on you, your job is in peril, and justly so, but you are the one most interested, and you should be studying your case continuously. Do not drift along waiting for the company to analyze the work in your department, be analyzing it yourself from day to day, so that when the management calls for a conference, you will be able to show them that your department has not only been turning in a profit, but has been conducted on a most economical basis.

Analysis not only of the individual, but of a department will be the best means of preventing in the next industrial crisis a return of the wholesale elimination of valuable employees in the physical, chemical and metallurgical laboratories.

PITTSBURGH SELECTED FOR 1923 CONVENTION

The Board of Directors of the American Society for Steel Treating, after having given the location of the 1923 convention city very serious consideration and a committee had visited the cities under consideration, voted to hold the 1923 Convention and Exposition in Pittsburgh at the Motor Square Gardens during the second week of Oct. 8 to 12 inclusive.

The selection of Pittsburgh because of its central location, and being the center of steel production of the country, and the active support and co-operation that will be given by the local chapter will meet with the most general approval of the entire membership and the exhibitors. The exposition will be held at the Motor Square Gardens and floor plans are being prepared now for distribution. The meeting rooms will be in the same building as the exposition.

FAREWELL RECEPTION TO DR. STRATTON

IN HONOR of Dr. Samuel Wesley Stratton, director of the national bureau of standards and president-elect of the Massachusetts Institute of Technology, a farewell reception was held Thursday evening, December 14, 1922, from 7:30 to 11 p. m., in the Industrial building laboratories, department of commerce, bureau of standards.

Between the hours of 7:30 to 9:00 members of the staff and their guests held a reception to Dr. Stratton. Also during these hours a trip through the laboratories of the Industrial building had been arranged. Many interesting pieces of apparatus were in operation. Notable among these were the cement testing and stone sawing apparatus; the cement kilns; the enamel furnaces; the general ceramic kilns; the glass plant where glass was being melted; the paper mill, which was in operation; the textile mill and the rubber laboratory.

At 9 p. m. all of the staff members and guests assembled in center wing of the building at which time Secretary of Commerce Herbert Hoover briefly addressed the assembly expressing his sincere regrets that Dr. Stratton was leaving the bureau. In commenting on the resignation of Dr. Stratton he said that the loss of Dr. Stratton as head of the bureau of standards is a real national loss. He has built up that service from a bureau devoted to scientific determination of weights and measurements to a great physical laboratory co-operating with American industry and commerce in the solution of many problems of enormous value in industry which the commercial laboratories of the country, from lack of equipment and personnel, have been unable to undertake. He added that every possible effort would be made to secure a successor to Dr. Stratton who would carry forward the most excellent work that has been planned and a great deal of which has been executed during the 21 years of Dr. Stratton's service.

Secretary Hoover then turned the meeting over to Dr. Holbrook, who reviewed at some length the work that had been accomplished by Dr. Stratton and the bureau of standards.

In closing, Dr. Holbrook presented Dr. Stratton with a silver tea service and table which he will take with him upon his departure from the bureau, as a token of the esteem which his staff has for him.

Dr. Stratton was considerably affected by this presentation and thanked his staff and colleagues most graciously. He then outlined in his speech, the wonderful growth of the bureau of standards. He reviewed the work of each of the departments indicating the important things which had been accomplished and those which were still under investigation, illustrating for example, the valuable data which had been obtained by engineers in the study of large railroad bridge members, in the 3,000,000-pound testing machine which was in the room in which the audience was seated. Numerous other examples were related in which the bureau had aided the advancement of civilization.

In closing, Dr. Stratton said that he would always remain in close touch with the bureau and that the bureau's interests would always be his interests.

Following the general assembly, special exhibits selected from other buildings of the bureau were on display and most of them were in operation. Coincident with this exhibit, dancing was in order on the floor below. The

United States Marine band furnished the music for this enjoyable period which ended all too soon.

WINTER SECTIONAL MEETING

The Winter sectional meeting of the A. S. S. T. will be held in the city of Chicago on Feb. 8 and 9, at the City Club. The arrangement of the program and details are in charge of the executive committee of the Chicago Chapter of which Harold Wood, metallurgist with the Wyman-Gordon Co., Ingalls-Shepard Division, Harvey, Ill. is chairman and Harry Blumberg of the Illinois Steel Co., is Secretary.

It is planned that on Thursday, Feb. 8, the afternoon and evening will be occupied by the presentation of technical papers with a dinner meeting in the evening at the City Club. On Friday the ninth there will be no papers presented, but those in attendance will be given an opportunity to visit industrial plants in Chicago and vicinity in case they care to do so.

The regular quarterly meeting of the Board of Directors will be held at the City Club on Friday.

The Chicago chapter is planning an exceptionally fine program and it is urged that all those who can possibly find the opportunity should attend.

NOMINATING COMMITTEE FOR 1923 APPOINTED

PRESIDENT T. D. Lynch of the American Society for Steel Treating has announced the appointment of a Nominating Committee for the selection of National officers for 1923 and 1924. The personnel of the committee represents five of the chapters of the Society, distributed geographically and recommended for appointment on this committee by the various chapters. The members of this committee were selected from those chapters that had not previously been represented on the Nominating Committee. The committee is as follows:

H. J. Stagg, Gen. Mgr., Halcomb Steel Co., Syracuse, N. Y. Chairman.

C. E. McQuigg, Metallurgical Engineer, Union Carbides and Carbon Research Laboratory, Inc., Thompson and Manley Sts, Long Island City, N. Y., Member.

Mr. Jerome Strauss, Metallurgist, Navy Yard, Washington, D. C., Member.

Mr. W. R. Chapin, Metallurgist, E. C. Atkins & Co., Inc., Indianapolis, Indiana, Member.

Mr. C. B. Swander, Metallurgist, Wagner Elec. & Mfg. Co, St. Louis, Mo., member.

The officers to be selected by this nominating committee are as follows:

President for one year
Second Vice-President for two years
Treasurer for two years
One member Board of Directors for two years

This committee will announce its selection of candidates for national offices in the June TRANSACTIONS. These new officers will be voted on by mail ballots sent to the members of the society and will assume office during the 1923 annual convention at Pittsburgh.

Voting members of the Society are requested to recommend to the committee, names of eligible persons for the elective offices.

RECENT RESEARCHES ON THE ELASTIC LIMIT

By Herman A. Holz

Abstract

This paper deals with a discussion of those properties of metals which are of vital importance in the design of engineering structures. It points out some of the fallacies in the use of the elastic limit, proportional limit, yield point and maximum strength in design. The practice of European engineers is briefly outlined.

The various types of machines or apparatus for determining the elastic limit, proportional limit, yield point etc., are discussed. A detailed description of the latest type extensometer as contrasted with those previously available constitutes the major portion of this paper. Numerous stress-strain diagrams taken of various ferrous and non-ferrous metals are shown.

The instrument described, operates on a principle similar to a mirror galvanometer in which the beam of light reflected by the mirror traces a path on a photographic plate. This principle eliminates the pencil friction of some of the older types of stress-strain curve plotting apparatus. The results obtained with this new type instrument permits of the study of certain peculiarities in the stress-strain diagrams of metals and alloys which were obscured in the diagrams plotted by the other earlier instruments.

General

FROM the standpoint of practical engineering and safety the *elastic limit* is undoubtedly the most important physical property of a metal. What the engineer desires to know from the metallurgist is the complete story of the behavior of metals up to their yield point. The actual breaking strength of metals is of much less importance.

A material is elastic with regard to any applied stress if a strain (the change of shape produced by stress) disappears when the stress is removed. Strain which persists after the stress that produced it is removed is called permanent set. Most metals are perfectly elastic with regard to small stresses and very imperfectly elastic with regard to great stresses. In general, within certain limits the strain produced in metals is small in amount and disappears entirely when the stress is removed. If the applied stress exceeds this limit, the strain is much greater than before and when the stress is removed most of it is found to consist of permanent set.

The maximum load, expressed in pounds per square inch or equivalent units, which can be applied without causing a permanent set is called the elastic limit of the material. Engineers in some European countries use as a specification for elastic limit, that load which is required to cause a permanent set of .02 per cent on a 20 centimeter specimen, using an extensometer reading to one ten thousandths millimeters. This limit has been established because in practice it has been difficult to determine the actual maximum load which can be applied without causing any permanent set whatever. This difficulty is quite similar to the one encountered in research work on the

---

A paper presented before the annual convention of the Society, September, 1921. The author, Herman A. Holz, is president of Holz & Co., Inc., New York City.

hardness of metals, where it would be desirable to put a load on a ball which would just fail to produce any indentation in the material under test, however, due to mechanical difficulties this method of test has not been perfected.

Hooke's Law

According to Hooke's law enunciated by him in 1676, the strain produced by a stress within the limits of elasticity of a material is directly proportional to the stress producing it. In applying Hooke's law to the case of simple longitudinal stress, such as the case of a bar stretched by simple longitudinal pull, we can measure the state of strain by the change of length per unit of original length which the bar undergoes when stressed. Let the original length be l and let the whole change of length be cl when a stress is applied whose intensity s is within the elastic limit or the limit of proportionality. Then the strain is measured by cl/l and this by Hooke's law is proportional to s. This may be written

$$\frac{cl}{l} = \frac{s}{E}$$

where E is a constant for the particular material under investigation. Theoretically, the same value of E applies to compression and pull, inasmuch as both forms of stress are essentially continuous, differing only in sign. The constant E is called the modulus of longitudinal extensibility or Young's modulus. It is frequently called the modulus of elasticity, although this term is too general. There has not been a full systematic investigation undertaken regarding the temperature variations of these elastic conditions, but it has been established that there is a relation between the rate at which the elastic properties of metals change with temperature and their melting point.

Determination of the Elastic Limit Important

Returning to the practical conclusions which can be drawn from these theoretical facts, we must realize that in applying a knowledge of the behavior of metals to determine the proper sizes of parts in any engineering structure it is necessary to estimate a permissible working stress. It is the elastic limit rather than the maximum strength of material which determines the magnitude of the working stress that may be permitted with safety under any particular conditions of loading. Accordingly it becomes a matter of utmost practical importance to determine by careful tests the amount of stress which the material will stand without permanent strain, that is, we must determine the elastic limit.

Various Instruments Available
Martens Extensometer

Although the importance of the accurate determination of the elastic limit has been recognized by most research workers, the test has not become a routine test and has not been regularly carried out in American works practice, because the apparatus available in the past for real precise determinations have been rather complicated, being designed mainly for research work. The most reliable apparatus for accurate determinations of the elastic limit is the well known mirror extensometer designed by Martens,

which measures extensions to one ten thousandths of a millimeter. This apparatus, however, is capable of measuring only very small variations in length and requires considerable care and skill on part of the operator. The Martens mirror extensometer, as made by Amsler in Switzerland, is shown in Fig. 1 and 2, while the principle can be seen in the diagram Fig. 3.

Fig. 1 shows the standard instrument attached to a tensile specimen. Fig. 2 shows the apparatus with specially designed long mirror carriers applied

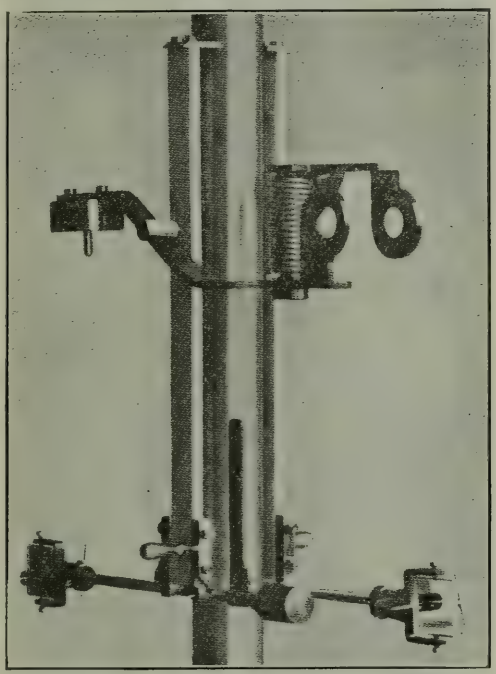


Fig. 1—Martens Mirror Extensometer Attached to Tensile Specimen

to a cylinder which is used for checking the calibration of test presses up to 1,000,000 pounds. Fig. 4 shows Amsler's observation apparatus consisting of telescopes, measuring scales and tripod, all mounted in such manner that each element can be adjusted separately in a horizontal and tilted position. This instrument operates in a manner similar to a reflecting mirror galvanometer. A detailed explanation of the formulas used in the calculations of results obtained with this instrument is unnecessary.

It may be of interest to note that a Martens mirror extensometer has recently been constructed and successfully used for research work on specimens heated up to 850 degrees Cent. In this modified apparatus, the general design was kept the same, but various parts exposed to high temperatures had to be made of special materials. It will be readily understood that since many of our steels, especially in essential parts of internal combustion engines, of boilers and many other pieces of apparatus and equipment, as well as many of our cutting tools are used at high temperatures, therefore, investigations of the elastic limit, hardness and other physical properties at elevated temperatures are of great practical importance.

Ewing Extensometer

Sir J. A. Ewing has designed a self contained microscope extensometer which is more convenient but not quite as accurate as the Martens mirror apparatus. In this apparatus, diagrammatically shown in Fig. 5, the exten-

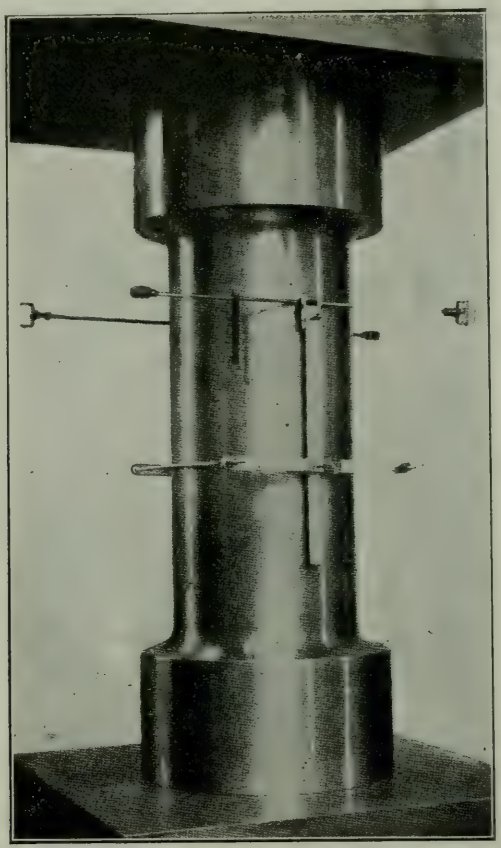


Fig. 2—Martens Mirror Extensometer With Long Mirror Carriers for Compression Tests

sion of specimen *A* is magnified by a system of levers *B'*, *C* and *Q* to a freely suspended rod R carrying a mark at its lower end, on which a reading miscroscope is sighted, carrying a micrometer scale in its eyepiece.

Dalby Extensometer

The greatest disadvantage of all such extensometers for practical work is that they require the closest attention of at least one operator, that they take up considerable time and that they are not autographic; the observations are taken at definite points, not continuously, and have to be plotted afterwards. These difficulties have recently been overcome by Professor Dalby of London who has designed an autographic optical load-elastic extension recorder which combines the features of great accuracy, speed, robust construction and complete elimination of the personal element. This apparatus

opens up a large field of possibilities for original research on the correlation of the true elastic limit with other physical properties such as fatigue resistance, notch-brittleness, ductility, etc., and makes it possible for the first time, to include accurate determinations of the elastic limit in routine tests. From the records obtained the true elastic properties of metals can be immediately deduced; the autographic curve produced by this ingenious apparatus, showing at a glance the limit of proportionality, furnishes data from which some new elastic constants can be studied.

This optical recorder, like all other scientific apparatus, went through several stages of evolution until it finally reached the stage of its highest development as shown in Fig. 6. In Fig. 7 the instrument is shown, set up in a specially designed testing machine. In Fig. 6, *W* is a bar of steel about one foot long, which is called the *weigh-bar*, while *F* is the specimen under test. The weigh-bar is attached at one end to the testing machine, while its other end is coupled to the test specimen, the lower end of the specimen being connected to the grip at the base of the testing machine. The weigh-bar

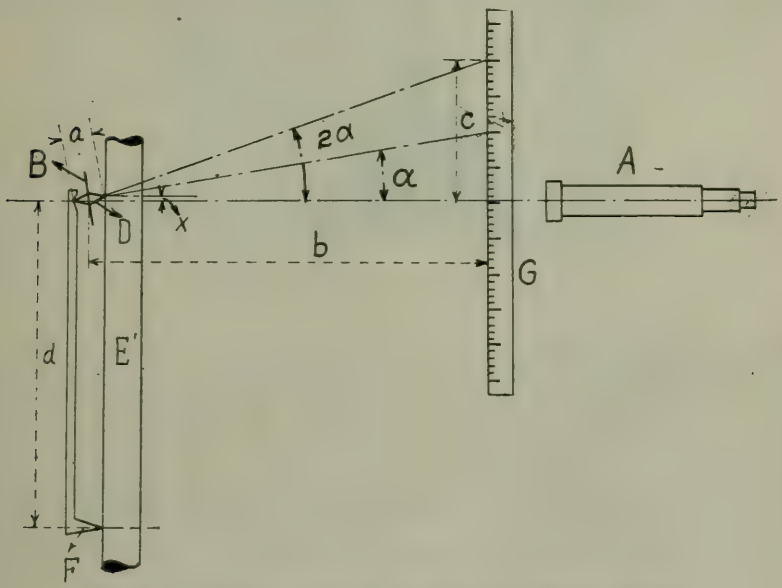


Fig. 3—Diagram Showing the Principle of the Martens Mirror Extensometer

and the specimen bar are then like two links of a chain stretched between the shackles of a testing machine, so that the pull applied by the machine is applied equally to both bars. The cross sections of the bars are proportioned in such manner that the pull applied through them is ultimately able to break the specimen bar without loading the weigh-bar beyond its elastic limit. The stretch of the weigh-bar is used to determine the load passing equally through it and the specimen. The apparatus is autographic, as a record of the load applied and the extension of the specimen is made by the movement of a spot of light over a photographic plate held in a camera attached to the weigh-bar. If the spot of light is focused on the ground glass of the camera, an increase of load moves the spot vertically and proportionally to the increase of gage length, but horizontally and proportionally to the extension of

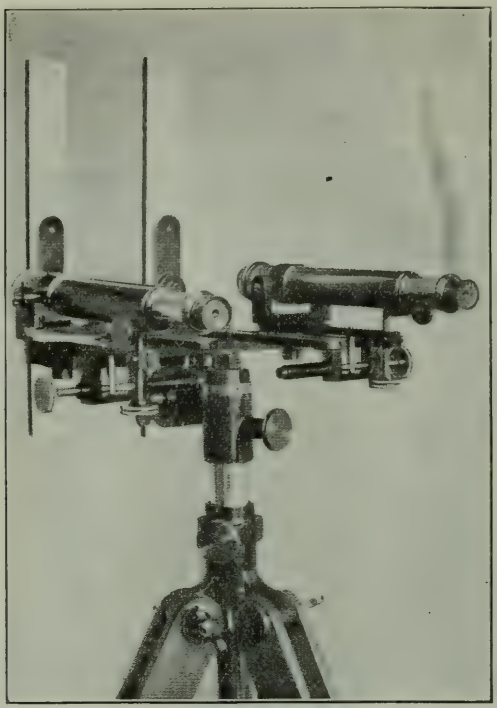


Fig. 4—Observation Apparatus for Martens Extensometer

the weigh-bar and therefore proportionally to the load on the test piece. This effect is produced by a system of suitably arranged mirrors and an electric incandescent lamp which is the source of light. Convenient adjustments are provided at *H* and *P* for setting the load zero and the extension zero. The extension of the gage length is transmitted to the optical lever within the weigh-bar by the chain of levers partly seen in Fig. 6. The microscope *R* is added for convenience, so that the extension may be watched as the piece stretches. An index is secured to one of the moving parts of the transmission gear, and when the microscope is properly focused and adjusted, this index is seen moving across a scale in the eyepiece. This enables the load to be stopped at any desired stretch. The load may then be removed and re-applied and varied as desired, because the effect of each variation is clearly seen in the field of the microscope. Watching the movement of the index in the field of the microscope is equivalent to watching the vertical movement of the spot of light over the camera plate on which it is focused. Regulation of the brilliancy of the light is effected by a special switch box seen in Fig. 7 at the base of the testing machine. An interrupter can be inserted into the circuit so that the light can be interrupted at definite intervals, for example every 1/10 or 1/20 second. This produces curves consisting of dashes and permits accurate time investigations of the various phenomena shown in the curves. Accurate curves have been taken within 2 seconds from zero to break, with the time occupied to the yield point of ½ second.

The absence of pencil friction in the diagrams brings out irregularities in the curve drawn that are due only to the behavior of the metal itself. In

the old style tensile machines, the friction from pencil and mechanism produces irregularities in such curves which prevent the true relation between load and extension from being accurately shown. In the photographic diagrams, the continuously changing relation between the change of load and the change of length can be seen directly from the curve, and the changing shapes of the curves reveal, by comparison, qualities of the materials which are essential to know. The advantages of possessing accurate load-extension diagrams may be briefly summarized: differences in quality are shown at a glance by merely comparing the shapes of the curves, and material delivered at any one time may thus be critically compared in quality with similar material delivered at any other time, presuming, of course, that the diagrams are taken from test pieces of identical dimensions. In particular, overstrained steel is immediately detected, because its load-extension curve differs markedly in shape from that taken from normal material. The tensile test, as ordinarily carried out, tells a very small part of the story which it can be made to tell if carried out by such refined apparatus, that is, apparatus which completely eliminates friction and inertia from the recording mechanism. Fig. 8 shows as much of a load-extension diagram as can be plotted from

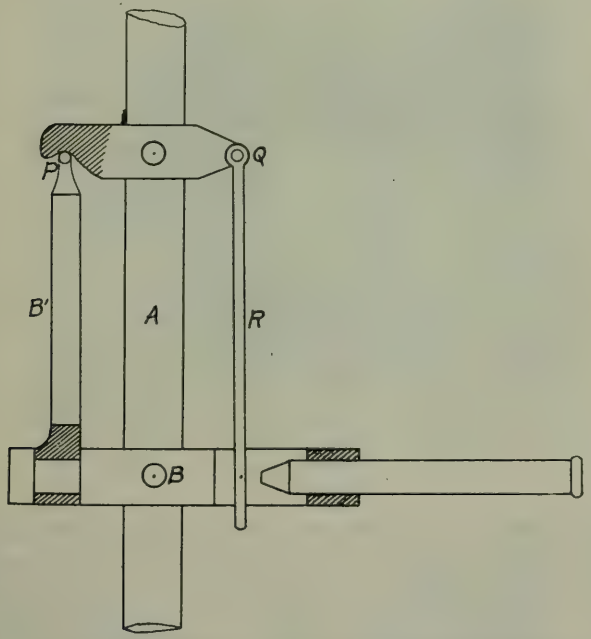


Fig. 5—Diagrammatic View of the Ewing Extensometer

the data of an ordinary tensile test. The data give yield-load with no corresponding extension, maximum load with no corresponding extension, maximum extension with no corresponding load. From these data it is impossible to plot a single point. We have at our disposal:

1. The ordinate of yield but not the abscissa
2. The ordinate of maximum load but not the abscissa
3. The abscissa at fracture but not the ordinate of load

From these considerations it will be evident why many defects in the quality of metals remained undiscovered in the ordinary tensile test.

Stress-Strain Curves Plotted by Optical Extensometer

We will now proceed to show the results of refined tensile tests which, instead of the half coordinates of three points, record a continuous curve which corresponds to complete coordinates an an infinite number of points. Fig. 9 is a correct load-extension curve of a piece of Yorkshire iron of quality *A*, while Fig. 10 shows the corresponding curve for Yorkshire iron of

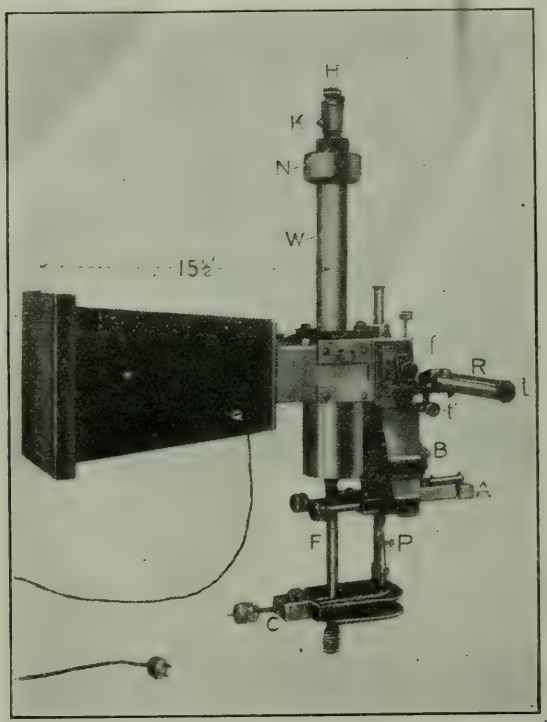


Fig. 6—The Dalby Autographic Optical Load-Elastic Extension Recorder

quality *B;* the diagrams are continuous from zero to break, and their shape is characteristic of the quality of this particular type of iron. Fig. 11 shows a curve taken on Staffordshire iron, and Fig. 12 one taken on Swedish iron. Fig. 13 shows a curve taken on electrolytic copper and Fig. 14 one taken on arsenical copper. While changes in the process of manufacture and treatment are clearly shown in changes in the shape of the iron curves, although they may not materially influence the yield-point, maximum load, and total extension, the contrast between the iron curves and copper curves is so great that they may be readily distinguished and classified. The curves of brass, phosphor bronze, aluminum, zinc, tin, etc., are all truly characteristic and easily distinguished.

Fig. 15 and 16 are the curves of mild steel .12 carbon and .22 carbon, while Fig. 17 and 18 are taken on carbon steels .42 carbon and .56 carbon.

As will be seen, the load-extension curves of iron and carbon steel are not continuous from zero to break, but show a discontinuity between the elastic

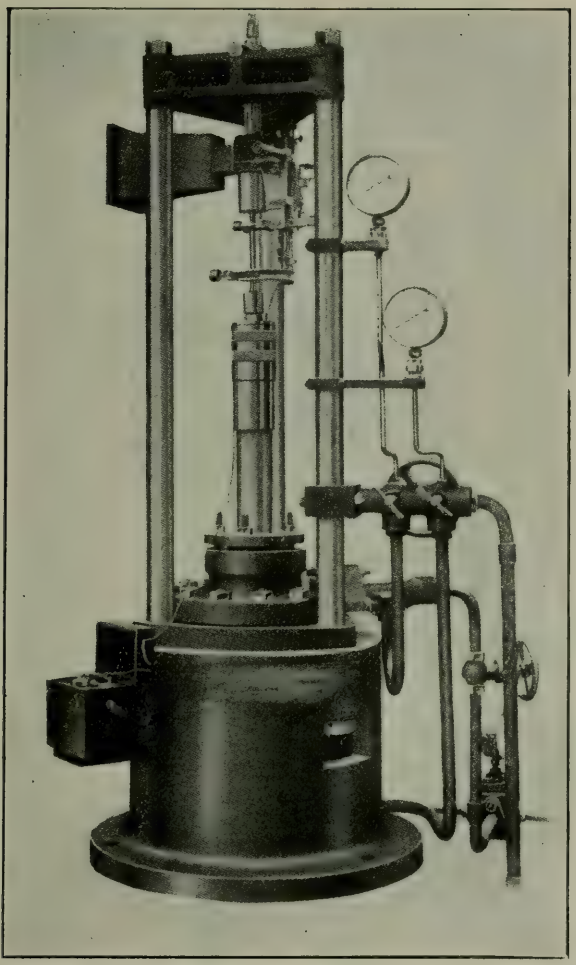


Fig. 7—Dalby Apparatus Mounted on Special Hydraulic Tensile Testing Machine

part which appears almost vertical in the diagrams, and the plastic part. The two parts are joined by a link, irregular in shape and suggesting that the passage from the elastic to the plastic state in these metals is not made without some profound molecular disturbance. It is an unsolved problem why iron and plain carbon steel should always show this link when in normal condition, while no other metal or alloy gives the slightest indication of it but changes smoothly from the elastic to the plastic state.

Speaking of these curves in general, it can be stated that any change in composition or treatment is shown in a slight change in the shape of the curve; however, the group characteristics of the curves for the particular metal on which the curve was taken is retained. A systematic recording of load-extension curves of material in routine testing practice would certainly be valuable, as any changes in composition and treatment are shown up in a manner which is unmistakable, if experience in the interpretation of the curve differences has been gained.

The character of the curves change as soon as any element is alloyed with steel. Notwithstanding the fact that carbon is still present, in alloy steels the change from the elastic to the plastic state is done smoothly, as will be seen in Fig. 19 (nickel-chrome steel, C .33, Mn .33, Ni 3.74, Cr 1.73). Fig. 20 (Hadfield's manganese steel C 1.26, Mn 11.75) and Fig. 21 (high nickel steel). In the Hadfield manganese steel, the plastic curve is replaced by a stepped curve and there is no local contraction. The bar extends uniformly and then breaks.

This new apparatus has also made it possible to investigate very carefully and conveniently the influence of the length of the specimens, shoulders of

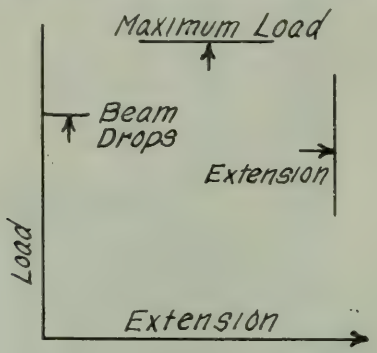


Fig. 8—Diagrammatic Sketch of Data Given by the Ordinary Tensile Test

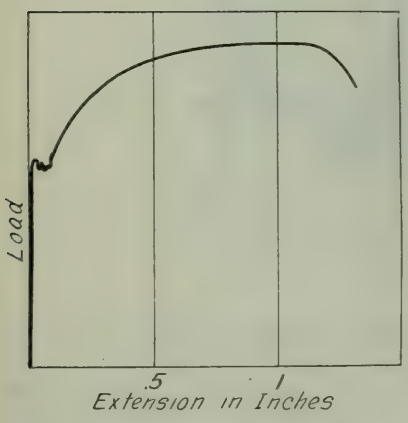


Fig. 9—Optical Load-Extension Curve Taken from Yorkshire Iron—Quality A. Extension on 5 Inches

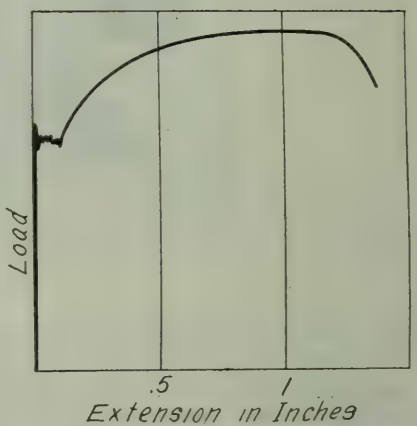


Fig. 10—Optical Load-Extension Curve Taken from Yorkshire Iron—Quality B. Extension on 5 Inches

the specimens, gage length on the extension, contraction of area, and also the influence of speed of testing on the final results. Several short specimens were broken in 1 second, obtaining during this second a complete load-extension diagram.

In the most recent researches undertaken, a special type of specimen was developed which was found to give most reliable results. In this specimen, shown in Fig. 22, the gage length is defined by flanges turned on the test piece itself. The ends of the arms of the extensometer rest on these flanges.

A gage length of 5 inches is used on iron and steels, while shorter specimens are used on the more ductile metals. The main reason for developing this flanged specimen was the difficulty encountered when pointed screws were to be driven into the specimens to define the gage length. The screws cannot be properly driven into hard materials like alloy steels, and in soft metals the

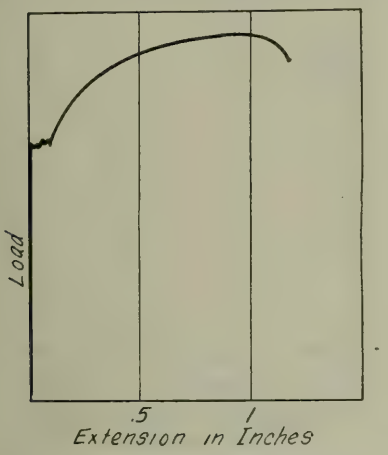


Fig. 11—Optical Load-Extension Curve Taken on Staffordshire Iron. Extension on 5 Inches

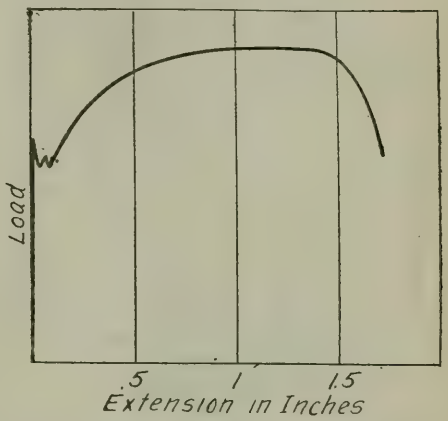


Fig. 12—Optical Load-Extension Curve Taken on Swedish Iron. Extension on 5 Inches

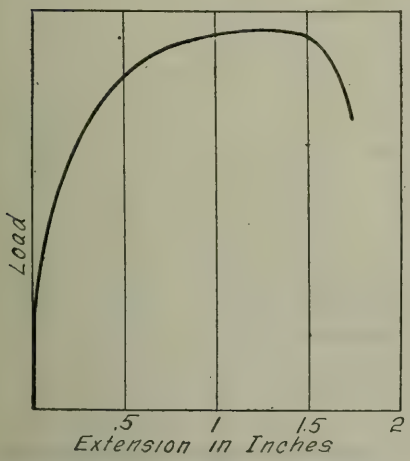


Fig. 13—Optical Load-Extension Curve Taken on Electrolytic Copper. Extension on 3 Inches

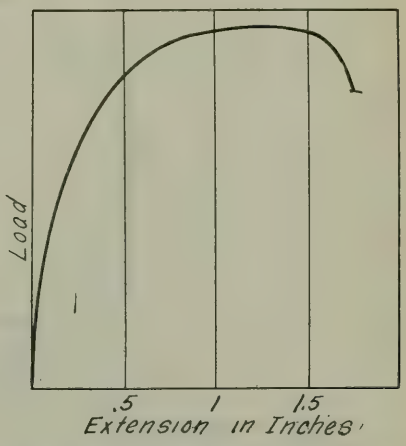


Fig. 14—Optical Load-Extension Curve Taken on Arsenical Copper. Extension on 3 Inches

center punch dot elongates during stretching and the gage points slip. The modulus of elasticity found from the flanged test pieces agrees with that found on plain bars. The flanges therefore have no influence on the elastic extension of the gage length, while they restrict the plastic extension very slightly. Professor Coker has investigated the distribution of stress produced by these flanges, by means of his well known method utilizing polarized light for studying stress distributions and found no stresses in the flanges them-

selves, but a slight and symmetrical modification of stress distribution at their roots. This means that as stretching proceeds the flanges are not distorted, and therefore the distance between the flanges is a true measure of the extension of the gage length which they define.

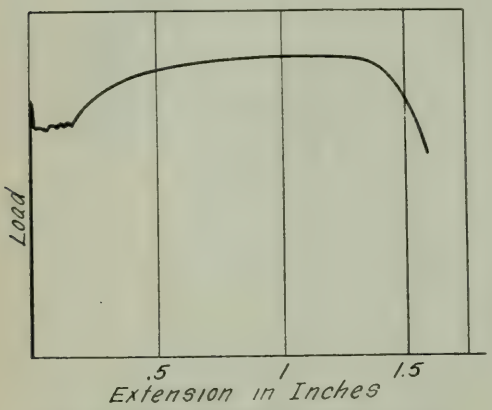


Fig. 15—Optical Load-Extension Curve Taken on Mild Steel. Carbon .12. Extension on 5 Inches

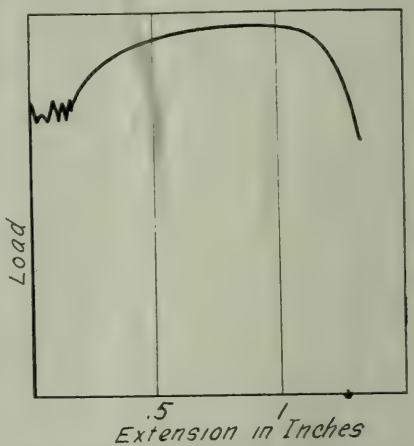


Fig. 16—Optical Load-Extension Curve Taken on Mild Steel. Carbon .22. Extension on 5 Inches

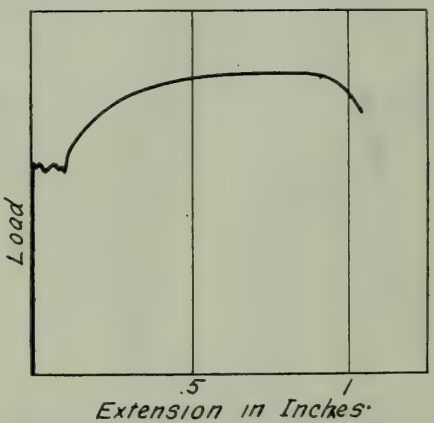


Fig. 17—Optical Load-Extension Curve Taken on Medium Carbon Steel. Carbon .42. Extension on 5 Inches

It has been seen that the power of complete recovery is lost when the stress produced by loading has once passed beyond a certain limiting value peculiar to the material. Below this limiting stress the extension of a steel specimen is proportional to the load producing it. Above this limiting stress the extension increases at a greater rate than the load. This limit is, therefore, called the limit of proportionality, but the term elastic limit is often used to define this point. The use of this term would seem to convey that the elastic power of the material is exhausted when once the stress has passed beyond the elastic limit and the material has passed into a plastic state. This is not true. The material possesses elastic properties right up to the instance of fracture.

If a specimen loaded nearly to the point of fracture is investigated in the testing machine, and the load quickly removed, the specimen will spring back. Precise measurements, however, will show that the relation between stress

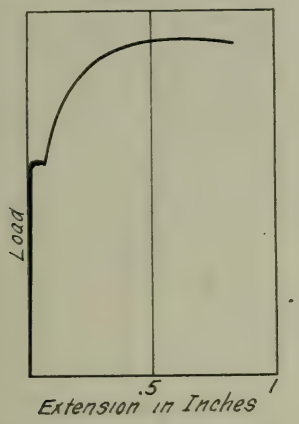


Fig. 18—Optical Load-Extension Curve Taken on Medium Carbon Steel. Carbon .56. Extension on 5 Inches

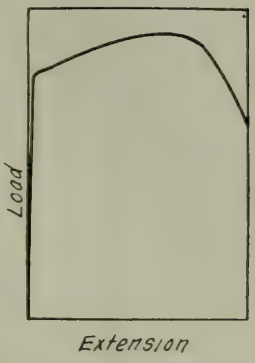


Fig. 19—Optical Load-Extension Curve Taken on Nickel-Chromium Steel. Extension on 5 Inches

and strain is then unproportional. The specimen fails to return to its original dimension by the amount of the permanent set. Professor Dalby uses the term unproportional elasticity to describe the state of the material under these circumstances.

If the loading on the specimen is stopped at any point after the elastic limit has been passed and then removed and afterward re-applied, the process involves the doing of work on the inner structure of the material and the record produced by the optical extensometer is a loop, the area of which represents the work done. Since the recorder is fitted with an observation microscope, the process of stretching and partial recovery can be conveniently watched as the experiment proceeds, and since the testing machine used is hydraulic, the load can be conveniently and rapidly released and reapplied.

Fig. 23 shows a looped diagram thus obtained on a specimen of nickel steel. It will be readily understood that the removal and reapplication of the load compels the spot of light to trace a loop. The area of the loop shows the kind of action that went on in the metal when it was stretched beyond the elastic limit and represents the internal work done during the process. Following the path of the spot it starts from the origin O and describes the elastic line OA, passes the limit of proportionality at A, and then curves away to the yield point B, and on to C. At C the loading is stopped, the hydraulic pressure is released by opening the exhaust valve, and the spot travels down the curved path CD as the load falls to zero. The exhaust valve is then closed, the pressure valve is opened, and the process is repeated through the path EF and so on. When the specimen has been stretched beyond its limit of proportionality, for instance to C in Fig. 23, the total extension is made up of two parts, namely:

1. The proportional elastic extension up to the limit of elasticity, for example up to A, in Fig. 23
2. The plastic extension after the limit has been passed

When the load is removed the steel shrinks unproportionally, for example

from C to D, by an amount approximately equal to its previous proportional elastic extension and then stops at a dimension greater than its original dimension by an amount approximately equal to its plastic extension. The increase of size measured after removal of the load is the permanent set: OD is the permanent set produced by the first stretching of the specimen to C. From the diagram this permanent set measures .0052 inch and the unproportional elastic recovery measures .011 inches. When the load is reapplied, the spot of light moves from D to E along a curved path. The extension is no longer proportional to the load. The metal is still in an elastic state, but of different nature. Stretching beyond the limit of proportionality has robbed

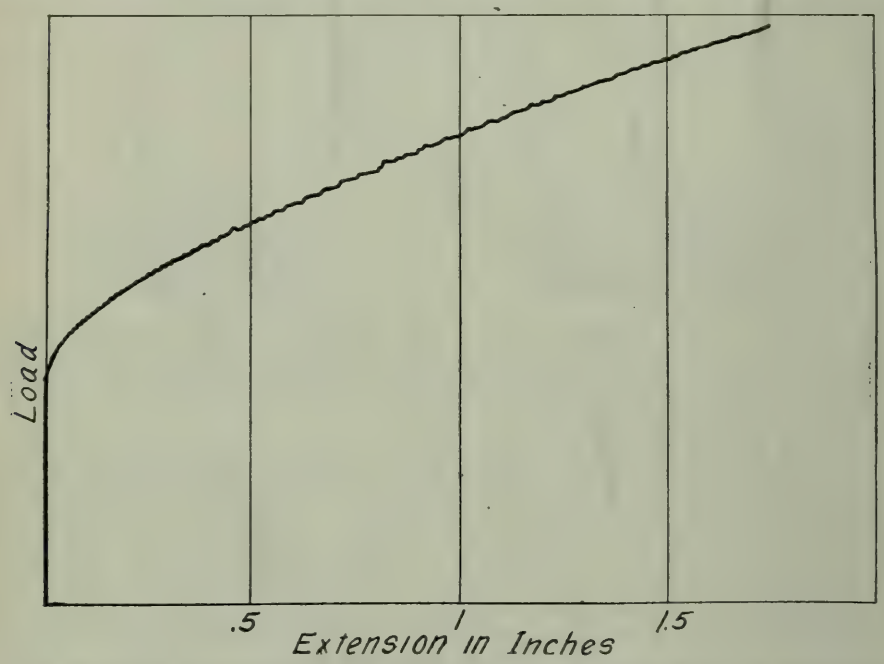


Fig. 20—Optical Load-Extension Curve Taken on Hadfield Manganese Steel. The Plastic Curve is Replaced by a Stepped Curve and There is no Local Contraction. Extension on 4 Inches.

the metal of its power of proportional extension and of perfect recovery after the removal of the load. The metal may be said to be in a state of imperfect elasticity or in a state of unproportional elasticity. The imperfect state is disclosed by the loop formed upon removal and reapplication of the load. The diagram in Fig. 23 shows four loops; each loop is slightly larger than the loop preceding it. Unproportional elastic shrinkage occurs in this metal right up to the load at which local contraction begins.

Some additional records of looped diagrams are shown in the following figures, and it will be seen that looping under applied, released, and reapplied loads is a distinctive property of each metal and alloy. The load scale was varied to bring out the shape of the loops. In the original photos, 1½ inches measured horizontally on the diagrams represented 1/100 inch extension of gage length. Figs. 24 and 25 are each .80 carbon steel, both specimens supposed to be material of identical quality and composition, but taken from different deliveries. While the general appearances of both diagrams is very

similar and shows that the specimens belong to the same family, they show clearly a difference in quality. On the first specimen, the limit of proportionality is reached at 8 tons of load, and the yield at 8.85 tons. There is a slight drop at the yield load. The areas of the loops are large and increase rapidly on successive tests. On the second specimen, the limit of proportionality ends at 3 tons of load and there is no definite yield point. The loop areas and their

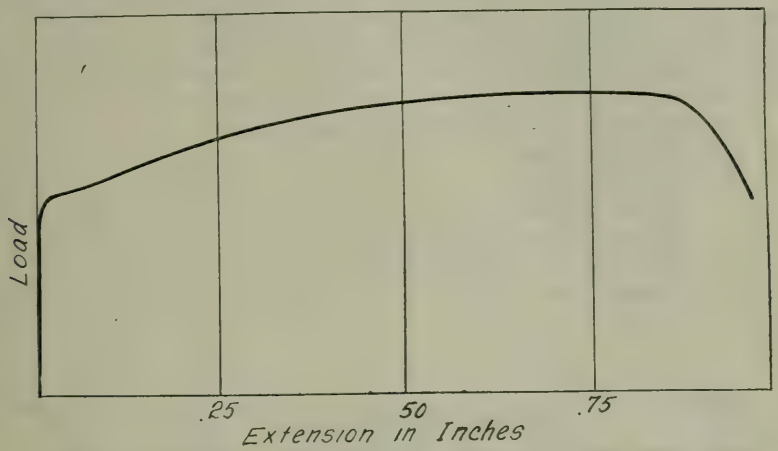


Fig. 21—Optical Load-Extension Curve Taken on a High Nickel Steel. Extension on 3 Inches

rates of increase are about equal in both diagrams. Another specimen investigated was a nickel chrome steel. The looped diagram is shown in Fig. 26. The ultimate strength of this material was found to be 54 tons per square inch, 14 per cent extension, 55 per cent reduction of area. The limit of proportionality was reached at 10 tons of load on a .625-inch specimen, corresponding to 32.5 tons per square inch. Yield sets in at 11 tons of load or 36

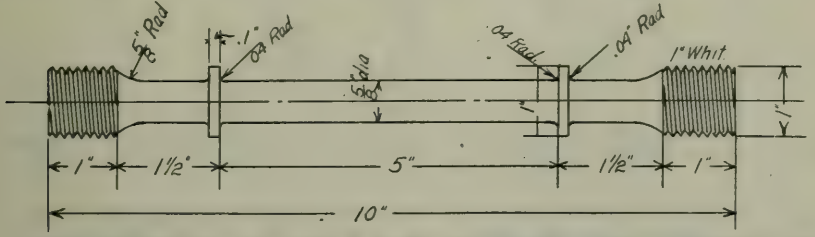


Fig. 22—Shows the New Type of Tensile Test Specimen Used in Connection with the Dalby Instrument.

tons per square inch. The first loop is small, but the areas of the loops increase quite rapidly, as seen in the 3 loops visible in the record. Very interesting loops have been obtained on zinc, tin, various coppers, brasses, phosphor bronze and aluminum alloys. The apparatus is designed in such way that the diagrams can be accurately and conveniently calibrated, and from such calibrated diagrams it is quite simple to calculate the area of the loops, the work done in elastic hysteresis, expressed in foot pounds per cubic inch of gage length, the modulus of elasticity, the stresses at the limit of proportionality and the stress at yield.

A general law has been found that the rate of increase of loop area decreases as the stretching proceeds and that the loop area tends to a limiting value. The few scattered observations shown in this paper are taken, more or less at random, from an enormous amount of research work done by Professor Dalby with this apparatus and show the possibilities of research opened up by this ingenious instrument. Systematic study of the looped diagrams, the loop areas and their rate of increase may well be expected to throw light on some of the properties of metals that are still hidden in obscurity; as this field is practically unexplored. At the same time, the data obtained will be of great practical importance and utility in industrial applications. The data that can at once be determined from the diagrams are:

1. The load at the limit of proportionality
2. The yield load
3. The modulus of elasticity (E) which is given by the slope of the elastic line
4. The work lost per loop
5. The rate of increase of the work lost per loop

The curve obtained from normal material satisfying known conditions of

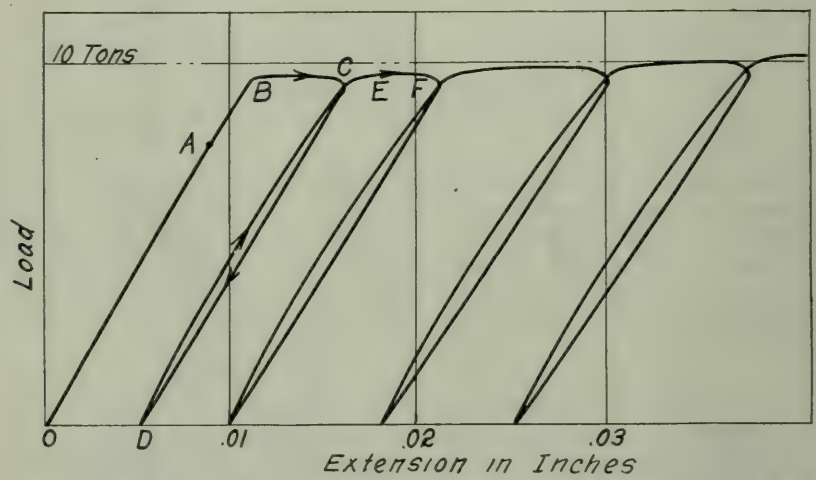


Fig. 23—Shows an Optical Load-Extension Loop Curve Obtained on a Specimen of Nickel Steel. The Removal and Reapplication of the Load Compels the Spot of Light to Trace a Loop.

composition and treatment may be used as a comparison diagram or standard. The form of the curve, the loop area and the rate of its increase, are very sensitive to small variations in the same kind of material, that is, to changes in the inner state of a metal. The diagram is especially useful in showing the load at the limit of proportionality, for this load bears neither a constant relation to the yield point, when there is one, nor to the ultimate strength. Consequently factors of safety calculated against either the yield load or the ultimate strength are ambiguous. This point is, for instance, of great importance in gun design, where the whole theory rests upon the elastic theory of the material and ceases to apply after the limit of proportionality is passed. Another important advantage of this method of investigation for practical work lies in the unification and co-ordination of existing tests which it permits.

Optical Extensometer Valuable in Routine and Research Work

It is difficult to predict whether this autographic extensometer will be of more value in routine tests or in systematic research work. It is safe to predict, however, that this apparatus will lead to some very valuable discoveries and important advances in metallurgical science. Just to mention one instance: it has been repeatedly shown during recent years that the various determinations made in conjunction with tensile tests at times fail to reveal

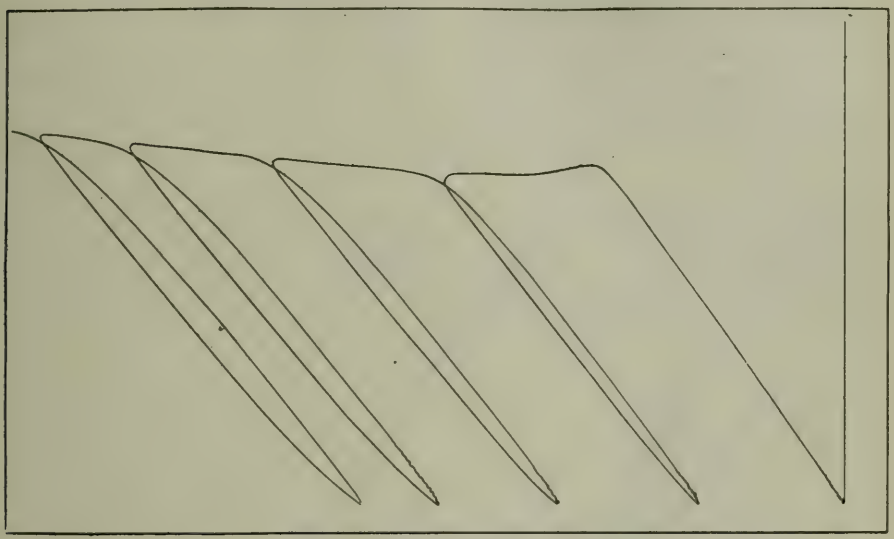


Fig. 24—Looped Optical Load-Extension Curves Taken on .80 Carbon Steel. The Load Scale was Varied to Bring Out the Shape of the Loop.

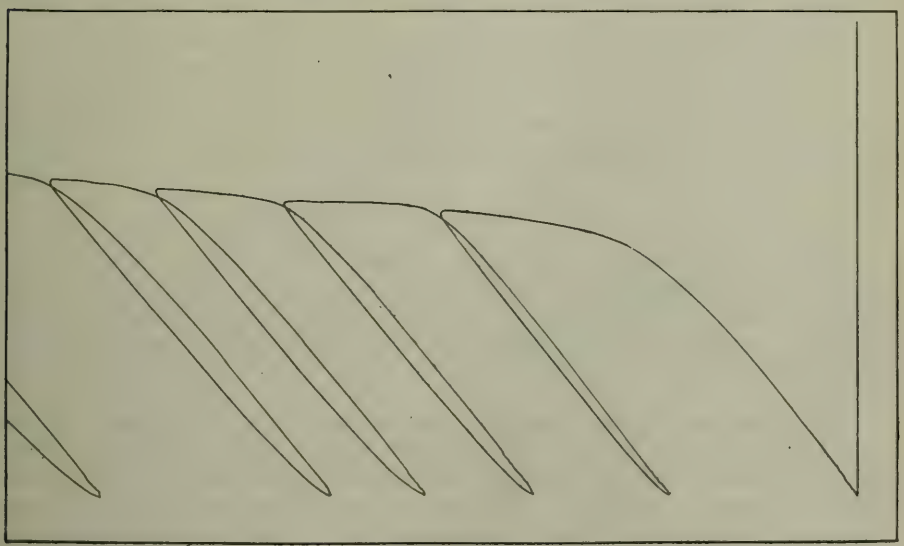


Fig. 25—Looped Optical Load-Extension Curve Taken on a .80 Carbon Steel. This Curve was Taken in the Same Manner as that of Fig. 24. The Steel was from Another Shipment.

differences brought out by notched-bar tests. This applies particularly to the so-called temper brittleness in certain alloy steels. There are instances where steels of the same hardness give widely differing values under the static and kinetic notched-bar test, and in many of these cases the tensile test and the microscope have utterly failed to give any indication of differences present in the material. This situation is now, however, remedied, because while the notched-bar tests bring out differences of quality which the ordinary tensile tests often did not reveal, the refined tensile test as carried out by means of this apparatus will show distinct differences between materials of different notched-bar values. With experience and standard diagrams as reference,

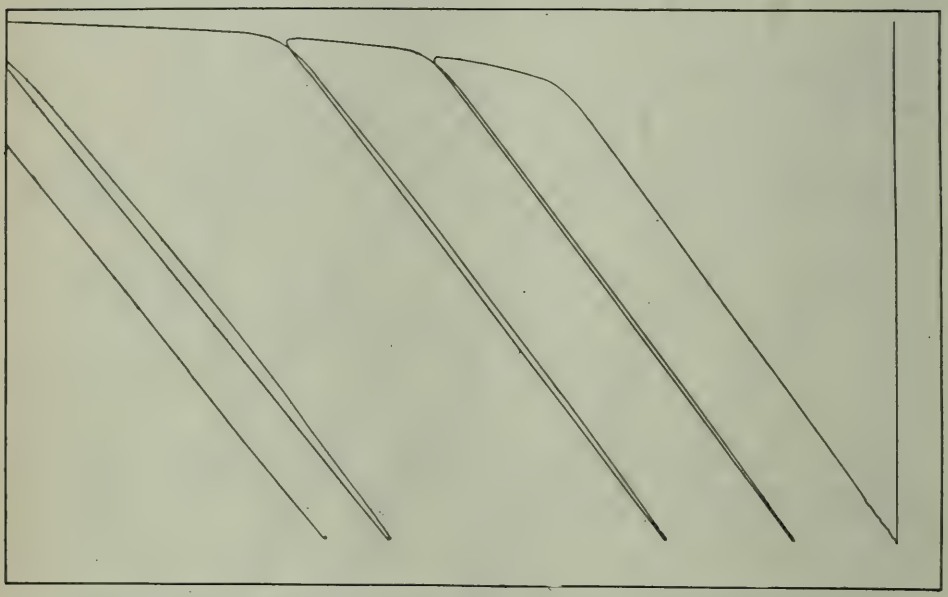


Fig. 26—Looped Optical Load-Extension Curve Taken on a Nickel-Chromium Steel

the optical load-extension curve and the looped diagrams will furnish all the information required about this quality of the material.

Overstrained Material Easily Detected

Overstrained material is at once detected by the slope of the curve. Furthermore, it is very probable that the limiting fatigue stress may be found by study of these elastic extension diagrams. Fatigue is a property of the metal while within the elastic range, and it seems that this apparatus lends itself admirably to investigations of the behavior of the material within that range.

The importance of such tests of material has been demonstrated by the recent disaster of the ZR 2. According to reports on hand at present, the accident happened while the dirigible made a sharp turn at top speed, under normal atmospheric conditions. We can presume that the British engineers designed and constructed the airship on a basis of correct figures for ultimate stress and elastic limit. But the huge frame was made of an alloy of which less is known of its mechanical properties than is known of steel. The vibra-

tions to which the framework was exposed at top speed of the various motors must have been enormous, and the detrimental influence of these vibrations combined with the enormous strain caused by a sharp turn, seem to have been the cause of the terrible disaster.

It is probable that in steel the limiting range of stress in fatigue has for its positive value the stress equal to the limit of proportionality. A series of specimens has already been investigated for this correlation and the results obtained show very close agreement. If it can be shown by further research work that these results can be generalized, it could be asserted that the load-extension curve shows the positive value of the fatigue limit. Extended investigations in this direction, over a wide range of materials, are also a promising field of research.

The limit of proportionality and other elastic constants can be determined automatically with this recorder and so quickly that there is now no reason why these important figures should not be included in the routine tests of metals.

Full credit is due to Professor Dalby for the excellent research work done in the development of this apparatus and its application to the increased knowledge of the elastic conditions of metals. We owe him thanks for furnishing the interesting information which forms the basis of this paper and for permitting the writer to submit it to our Society.

CARBIDE SEGREGATION IN HIGH SPEED STEEL

By A. E. White

Abstract

This paper points out that the degree of segregation in high-speed steel depends upon the casting temperature, the rate of cooling the ingot and the degree of mechanical reduction in the mills. Manufacturers of steel are cognizant of these factors and by careful control are attempting to eliminate as far as possible segregations in the final product.

The time is now ripe for experimental work in this field along lines somewhat more drastic than has been the case in the past. The user of tool steels usually has given little attention to these matters, his attention being from a complaintive rather than a constructive standpoint. The useful life of a tool rests as much in the hands of the user as it does in the hands of the manufacturer. Its life depends upon many factors, chief among which are the proper form of cutting edge, the rate of feed and the speed at which either the tool or work is moving as well as the necessity of proper lubrication. It is indicated that the next few years will bring about fundamental improvements in the manufacture of high-speed steel and that it is necessary that the consumer and manufacturer work closer together.

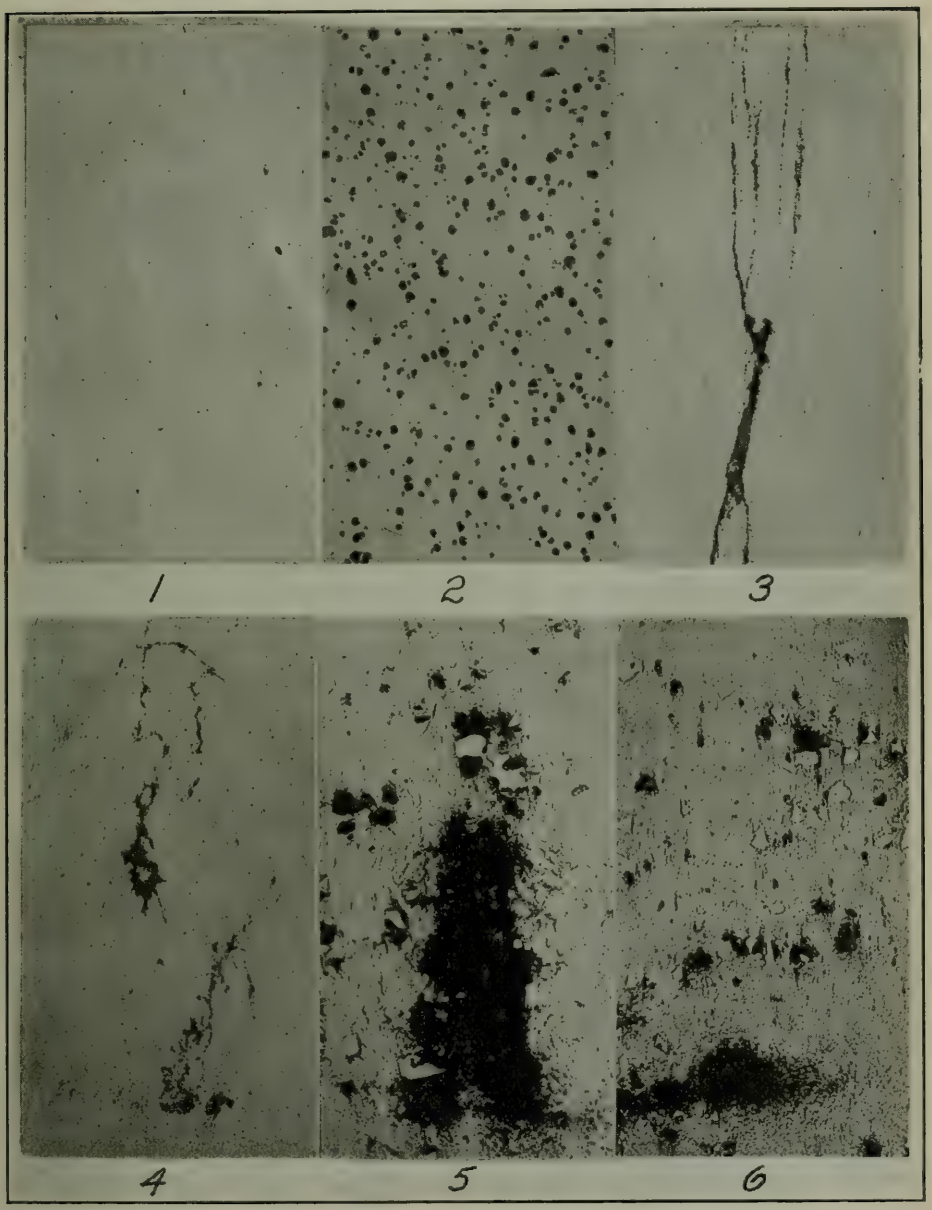
IN 1784, at approximately the time when this nation was founded, crucible steel was first produced. In 1900 Taylor and White announced to the world high-speed steel. Since 1900 there have been no outstanding changes in the composition of this steel and since 1784 there have been no outstanding changes from a metallurgical angle, although there have been outstanding changes from a fuel efficiency angle, in the crucible process. This is the process by which large quantities of high-speed steel are today made.

Beginning with the 20th century there has been an increased use of the electric furnace. This type of furnace and the crucible furnace share the honors in the making of high speed steel. The electric furnace has not been universally adopted for this class of work and there are those that state, among them the firm that first introduced an electric furnace into this country, and who are strong advocates for its use in the production of alloy steel, that the crucible process, by and large, is superior to the electric furnace process for the production of high-speed steel.

It is not the purpose of this paper to defend either the crucible or the electric furnace process. Each one has certain advantages over the other, and the question as to superiority therefore, becomes fundamentally more a question of plant operation than of process superiority. Thus in the electric furnace it is possible to get higher temperatures; with a resultant possibility of slag diminution in the steel. On the

---

A paper presented at the Detroit Convention of the Society, October 2-7. The author, A. E. White, is director of the Department of Engineering Research, University of Michigan, Ann Arbor, Mich.



HIGH SPEED STEEL DEFECTS

Fig. 1—Cross Section of an Average Acceptable Structure. Fig. 2—Cross Section of Specimen Showing Excessive Inclusions. Fig. 3—Longitudinal Section Showing Typical Slag Inclusions. Fig. 4—Cross Section Showing Typical Slag Inclusions. Fig. 5—Longitudinal Section Showing Badly Contaminated Metal. Fig. 6—Cross Section of Same Specimen as Fig. 5. All Specimens Are in the Unetched State. All Magnifications. X 100

other hand, the impracticability, one might almost say the impossibility, of accomplishing any refining in the crucible process gives greater assurance of a better deoxidized metal and in the production of steel in which a master ladle is not employed a probable decided reduction of the entrained slag content. These respective advantages are presented for the purpose of pointing out the probable impossibility of dogmatically stating that one process, because of the process itself, is superior to the other.

Governing Factors

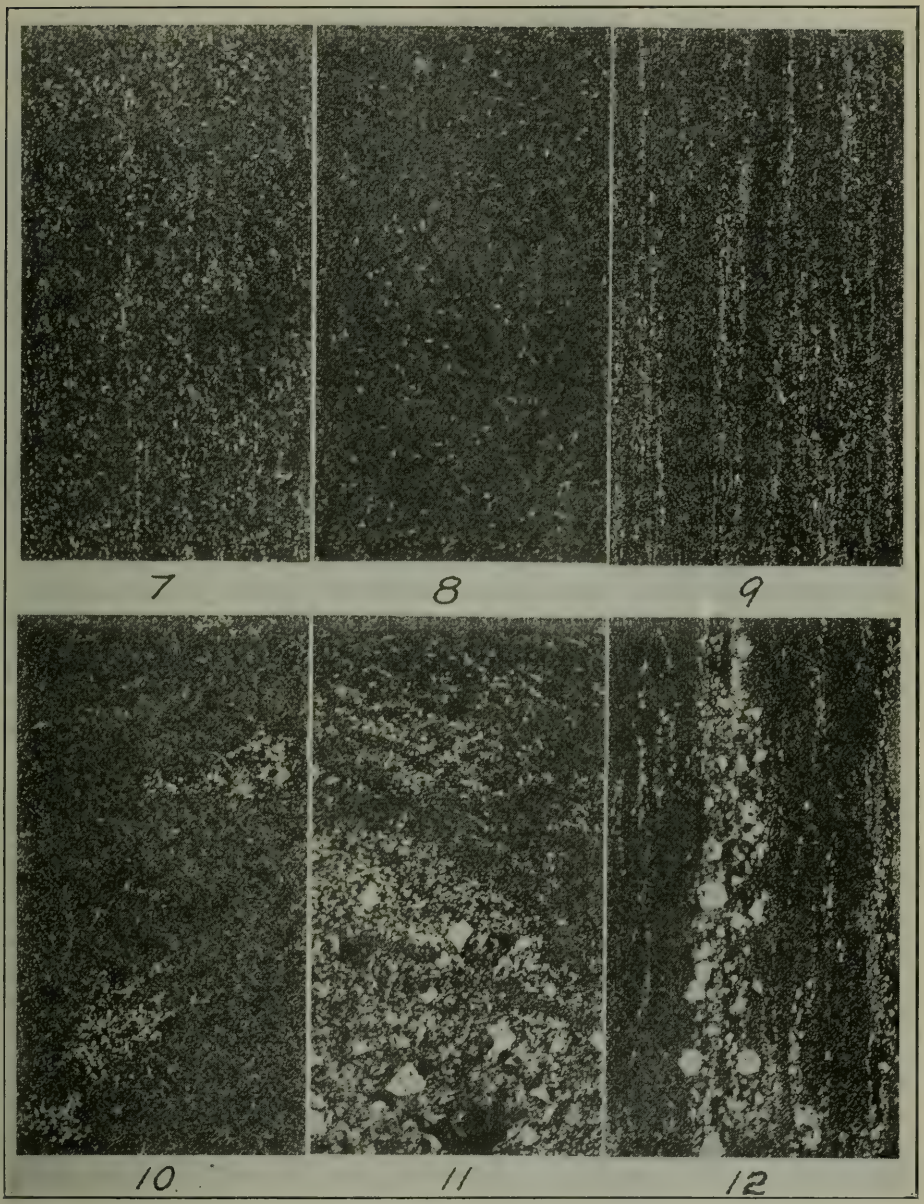
The troubles generally encountered in high-speed steel chargeable to the steel manufacturer are not due to the refining or melting methods employed, but rather to the conditions which take place during the cooling of the steel from the molten to the solid state. Certain of these defects are chargeable to faulty practice and any steel manufacturer thus guilty usually acknowledges the trouble and willingly replaces the steel. Thus steel with an excessive quantity of contained slag is of this type.

Several photomicrographs illustrating this condition setting forth both the good and the bad are submitted. Fig. 1 represents the average unetched appearance of acceptable stock. Fig. 2 represents the appearance in an unetched condition of bar stock containing a large number of evenly distributed inclusions. Figs. 3 and 4 show slag inclusions in the longitudinal and cross sectional views of bar stock. Though not universally present in high-speed steel, yet inclusions of this size are frequently encountered. Figs. 5 and 6 illustrate the appearance of steel excessively defective. Fig. 5 is a longitudinal section and Fig. 6 is a cross section. These defects are due entirely to what is recognized to be faulty manufacturing operations. They are not universally present and but a small percentage of the steel is thus defective.

The outstanding trouble in high-speed steel chargeable to the steel mill is segregation of the carbides. The elimination of this trouble is not in sight. It is a trouble resulting from the tendency on the part of the components making up a metal, especially the carbides in high-speed steel, to segregate. As long as cooling methods of a type which allow segregations to take place are employed, just so long will this trouble be found in high-speed steel, especially in the steel of the larger sizes. Numerous types of segregation found in current bar stock are submitted in photomicrographs Figs. 9 through 12 inclusive.

The excessive segregations can be lessened and in some cases eliminated provided the metal is reduced in cross section sufficiently, but in many of the commercial sizes of high-speed steel it is impossible to provide the required degree of reduction. For the most part it is present to a greater degree in the interior of a given piece than it is in the exterior of a given piece. For instance, photomicrographs Figs. 13 and 14 indicate the appearance of the longitudinal section and photomicrographs Figs. 15 and 16 the appearance of the cross section at the center and at the outside. A decidedly segregated structure is noted in those taken at the center and an absence of bands is noted in the others.

Micrographs Figs. 17 and 18 set forth the part location of sample



TYPES OF CARBIDE SEGREGATIONS IN HIGH SPEED STEEL

Fig. 7—Longitudinal Section Showing Excellent Structure. Fig. 8—Cross Section of the Same Specimen. Fig. 9—Longitudinal Section Showing Average Structure at Center of Bar Stock Over ¾ Inches in Diameter. Fig. 10—Cross Section of Same Specimen. Fig. 11—Cross Section of Badly Segregated Stock. Fig. 12—Longitudinal Section of Same Specimen. All Magnifications X 100

plays in the matter of carbide segregation more effectively, possibly, than the photomicrographs.

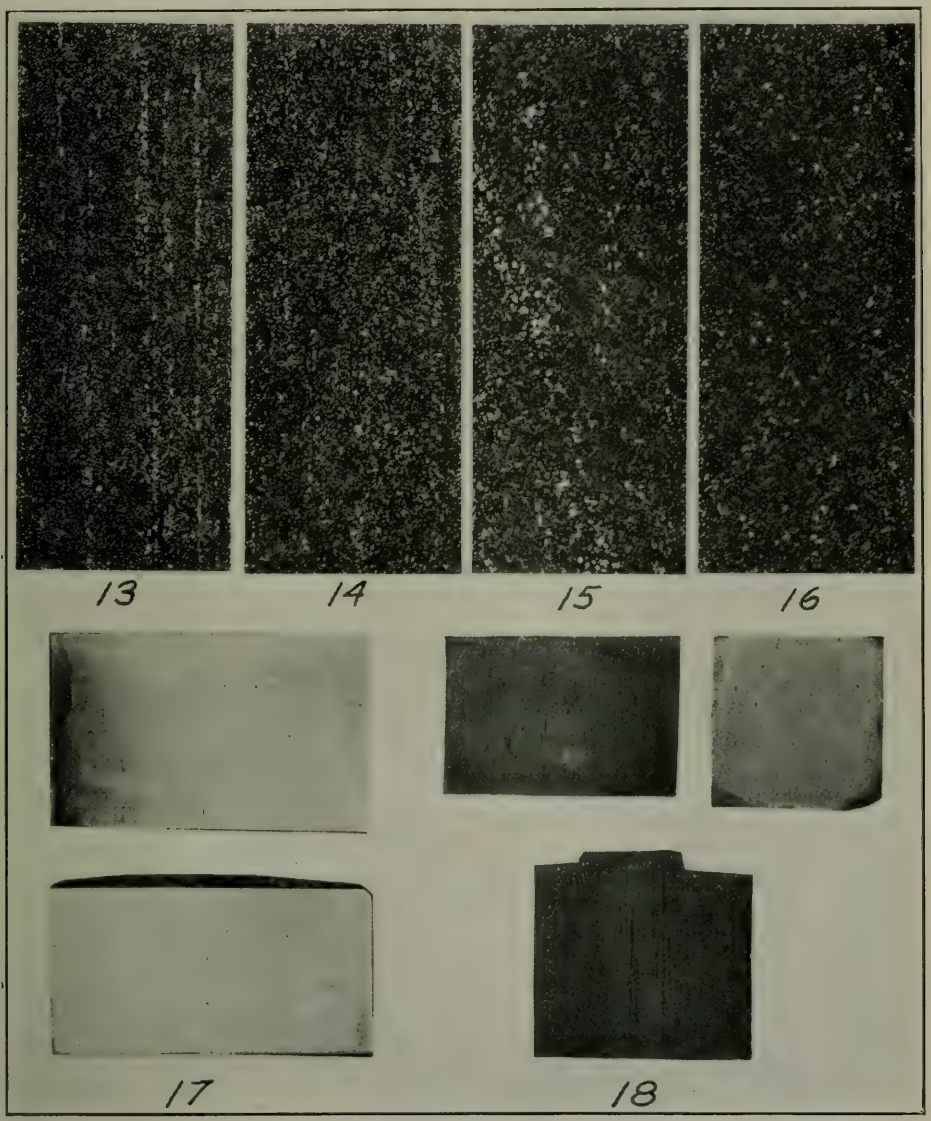
Casting Temperature Important

The degree of segregation is dependent upon initial casting temperature, rate of cooling from the liquid to the solid state, and degree of reduction. All of these factors are appreciated by the steel mills and there is no question but that all of the mills are engaged in a sincere effort to so control these factors as to get minimum segregation. Yet these efforts, commendable as they are, appear to be in the form of a palliative rather than a cure. The time is ripe for experimental work in this field along lines somewhat more drastic than has been the case in the past when we consider there have been no changes of moment affecting the elimination of segregation for over a hundred years. Is the time not now ripe for a thorough investigation of this matter? Can we this day answer what effect the centrifugal casting of high-speed steel would have in the elimination of this segregation? Or who can predict what would be the effects of casting under pressure, or what effects would result from radical changes in the reduction operations or from a radical change in the shape into which the steel is first cast? May we not go so far in our imagination as to wonder if the day will come when we will convert steel from the liquid to the solid state by some such process as is now used in converting molten glass to solid glass? Especially worthy of consideration is the investigation of the effect of centrifugal casting on the elimination of segregation. This is a matter which it is believed should be given a most thorough trial in order to ascertain if it would not materially reduce segregation.

No attempt has been made to prepare this paper from the standpoint of either the high-speed steel manufacturer, the tool manufacturer or the tool user. There are men in each of these three lines, who, because of their special privileges and opportunities, are in a much better position to speak on this subject than is the writer. As a matter of fact, some very excellent presentations in these fields have been made by some of our steel mill metallurgists and by some of the metallurgists connected with certain of our tool manufacturing establishments, although it is with deep regret that the policies of certain companies in this field prevent their men from taking part in these discussions to a degree that would be of greatest benefit.

The consumer has given little attention to these matters. Such attention as he has given has been rather from the complaint rather than from the constructive side. Intelligent consideration must be given to this whole subject. To give the greatest life high-speed steel should be of the proper composition and free from segregations and inclusions. These are matters primarily chargeable to the manufacturer. Also for the greatest service the steel should be converted into a tool possessing a proper shape, a proper edge and, if shipped from the tool manufacturer's plant in the hardened condition, a proper degree of hardness. These are conditions which are fundamentally chargeable to the tool manufacturer. For further satisfactory service a tool must be at all times properly sharp, it must have the proper angle for cutting, it must be properly lubricated, it must be run at a proper speed, there

must be a proper rate of feed, there must be an absence of an uneven loading, and proper care and supervision must be taken in other matters of a similar character. It would appear, therefore, that proper tool life is as much in the hands of the consumer as it is in the hands of the steel manufacturer or tool maker. Experiments of any type are ex-



RELATION OF LOCATION OF SECTION TO CARBIDE SEGREGATION IN HIGH SPEED STEEL

Fig. 13—Longitudinal Section at Center of Bar. X 100. Fig. 14—Longitudinal Section at Edge of Bar. X 100. Fig. 15—Cross Section at Center of Bar. X 100. Fig. 16—Cross Section at Edge of Bar. X 100. Fig. 17—Entire Sections of Bars. X 1.75. Fig. 18—Entire Sections of Bars. X 1.75

pensive. Ultimately someone must pay that cost. If researches are instituted by a steel mill which result in an improvement in their product with a resultant demand for their product, the costs of such research are, in the end, unquestionably paid by the consumer. The consumer is the one that most benefits and also the one who pays the cost of the work.

Conclusion

It is very probable that the next few years will witness some very fundamental improvements in the manufacture of high-speed steel. It is hoped, however, that the triangular bond between the steel maker, the tool maker and the tool user, each to the other, will be appreciated, and that through co-operative work results will be forthcoming which will give to industry tools possessing the proper characteristics for maximum service.

THE EXECUTIVE AND RESEARCH

By John A. Matthews

Abstract

The author of this paper who is a very capable metallurgist, having gone through the periods of early training, in the shop, mill and laboratory, has arrived at the high station of chief executive of his company. His paper gives the viewpoint of an executive and the thoughts he has developed are very valuable. His views are particularly valuable because he can share mutually the viewpoints of the research worker and his problems. Likewise he shares mutually the viewpoints of the executives who must direct the policies of their organizations.

THE popular conception of research, I am convinced, is a misconception. To the man in the street research suggests a laboratory and a genius of the high-brow type presiding over it. He is generally supposed to be a dreamer and probably impractical. Interest in the results of research as far as the public is concerned, is apt to be centered in those that appeal to the imagination rather than to reason. The spectacular invention or discovery is what is expected by the public from a research laboratory. The plain literal meaning of the word research—to search again, the facts, processes and phenomena of everyday life to find new relations, laws and results, is less often considered and this phase is of less general interest to the public mind. The full definition of research is to search or examine with continued care; to examine into or inquire about diligently. The field of research is not, therefore, limited to science; it embraces all branches of knowledge and human endeavor, of conduct, economics, history, civics, and religion, as well as science and engineering.

The Executive's Function

The executive function has to do with executing, performing or carrying into effect laws, policies or orders of higher constituted authority. By definition the executive is not supposed to originate actions but to carry out the wishes and instructions of others. This is not true today, even of the President of the United States, notwithstanding the specific functions laid down in the constitution for the three branches of government,—Executive, Legislative and Judicial. It is not true in business, either, for the modern executive of a great corporation must possess initiative and is, in fact, more or less of a dictator of policies. His authority is so absolute that the function with which he is often connected is that of executioner,—cutting off heads of subordinates. That is a mistaken view, frequently born of unhappy experiences and it should be remembered that every executive desires most strongly to build up and not destroy. Even though he may be a dictator in a certain sense, he is held accountable for his acts by the stockholders and their chosen representatives, the directors. He is, in fact, between an upper and nether millstone—the avaricious stockholders and the more avaricious employes, the one demanding more profits and lower costs, and the other more money and less production. How else can a man in that position satisfy everyone without the aid of research, not research of the narrower sort from

A paper presented before the Detroit Convention Research Symposium, Oct. 2-7, 1922. The author, Dr. John A. Mathews, is president of the Crucible Steel Company of America.

a special laboratory and special group of men, but research in its broadest aspect as affecting every operation, process and product, participated in by technicians, foremen and superintendents and not infrequently by alert workmen?

In an address to the engineering division of the National Research council, about a year ago, I said that commercial research has for its principal purpose the increasing of profits. That is what manufacturing concerns are operated for and all departments of the organization must be co-ordinated so as to lead to profitable operation. Without this, failure is inevitable. Legitimate manufacturing profits are the reward the public pays for services rendered or risk taken. The desire for profits is the impelling motive that leads investors to take risks and build up industries that give employment to others.

The Research Department's Function

The research department of a company may function in many ways to contribute its part to this success; 1. It may endeavor to improve the product which leads to greater demand, larger output, greater ability to meet competition, and the ability to command higher prices. 2. It may direct its efforts toward lowering costs (a) by finding cheaper but satisfactory raw materials: (b) by improving old processes to increase yield or decrease labor, or both; (c) by developing new products and finding uses for by-products; (d) by finding new uses for existing products; (e) by improving operating conditions in the plant not directly connected with the product itself, such as effecting savings in water, fuel, lubrication and electricity, and by improving the working cycles, material movements and power conditions. All of these result in public good and bring their reward because they lead to better goods, cheaper goods, or the better supplying of the public needs.

Research in this broader sense, as well as in the restricted sense of the pure scientist must be actuated by the spirit of a search after truth. The fact that the research is for a specific purpose—profits—must not be allowed to interfere with the spirit and method that should control all research efforts whether the object is truth for truth's sake, or truth for profit's sake.

It is improbable that commercial research can adopt co-operative methods in peace times, to the extent that is possible in pure science efforts, where the competitive factor is lacking. There are exceptions to this, however, as is evidenced by such splendid examples of co-operation as in the study of the fatigue of metals, of rock-drill steels, the gage steel researches, all of which I have had the privilege of participating along with other steel men.

There will exist a natural bond of sympathy and understanding between the executive and the research worker, when each recognizes that his conclusions to be valid, must be arrived at by the same method,—the scientific method, whereby sound judgments are the result of a logical weighing of facts and events, their sequence and relationship. Each will better understand the other if he will ponder the words of Doctor Karl Pearson, quoted from his introduction to the "Grammar of Science," and in conclusion I will leave with you his words of wisdom upon the meaning, purposes and scope of science and the development of the scientific frame of mind.

Research—The Scientific Method of Examining Facts

"The classification of facts and the formation of absolute judgments upon the basis of this classification—judgments, independent of the idiosyncrasies of the individual mind—essentially sum up the aim and method of modern

science. The scientific man has above all things to strive at self-elimination in his judgments, to provide an argument which is as true for each individual mind as for his own. The classification of facts, the recognition of their sequence and relative significance is the function of science, and the habit of forming a judgment upon these facts unbiased by personal feeling is characteristic of what may be termed the scientific frame of mind. The scientific method of examining facts is not peculiar to one class of phenomena and to one class of workers; it is applicable to social as well as to physical problems, and we must carefully guard ourselves against supposing that the scientific frame of mind is a peculiarity of the professional scientist.

"*Science,* indeed, often teaches us facts of primary importance for practical life; yet not on this account, but because it leads us to classifications and systems independent of the individual thinker, to sequences and laws admitting of no playroom for individual fancy, must we rate the training of science and its social value higher than those of philology and philosophy. The first aim of any genuine work of science, however popular, ought to be the presentation of such a classification of facts that the reader's mind is irresistibly led to acknowledge a logical sequence—a law which appeals to the reason before it captivates the imagination. Let us be quite sure that whenever we come across a conclusion in a scientific work which does not flow from the classification of facts, or which is not directly stated by the author to be an assumption, then we are dealing with bad science. Good science will always be intelligible to the logically trained mind if that mind can read and translate the language in which science is written. The scientific method is the method of all logically trained minds. I believe more will be achieved by placing instruction in pure science within the reach of all our citizens, than by any number of polytechnics devoting themselves to technical education, which does not rise above the level of manual instruction.

Field of Scientific Research Unlimited

"The field of science is unlimited; its material is endless, every group of natural phenomena, every phase of social life, every stage of past or present development is material for science. The unity of all science consists alone in its method, not in its material. The man who classifies facts of any kind whatever, who sees their mutual relation and describes their sequences, is applying the scientific method and is a man of science. It is not the facts themselves which form science, but the method in which they are dealt with.

"Every great advance of science opens our eyes to facts which we had failed before to observe, and makes new demands on our powers of interpretation. This extension of material of science into regions where our great-grandfathers could see nothing at all, or where they would have declared human knowledge impossible, is one of the most remarkable features of human progress. Great as the advance of scientific knowledge has been, it has not been greater than the growth of material to be dealt with. The goal of science is clear—it is nothing short of the complete interpretation of the universe. But the goal is an ideal one—it marks the direction in which we move and strive but never a stage we shall actually reach. The universe grows ever larger as we learn to understand more of our corner of it."

GAS USEFUL IN HEAT TREATING ROOM

By J. Weaver Smith

Abstract

The author discusses the practical application of city gas or manufactured gas in the heat treating room. The convenience of using gas as a fuel is pointed out and its wide application to all types of industrial heating is shown in the accompanying illustrations.

Burner design, furnace design and the effects of using equipment of improper design are discussed. The wide application and ready accessibility of city gas has shown that it can be used economically and efficiently and compares favorably to other types of fuel. Furthermore it is clean and easily handled.

IT IS the purpose of this paper to offer a few practical suggestions as to what may be accomplished by the use of city gas for heating operations in and around the heat treating room.

In some instances the production manager, superintendent, or foreman, has been very liberal and provided appliances with great excess capacity for the work for which they were intended. On the other hand, the average man provides appliances which either have insufficient capacity or very inefficient operation, very little or no thought being given to burner design, and consequently the operation is usually a failure from an economical standpoint, and in many instances the actual production results desired are not obtained.

Today most gas companies maintain an industrial department of capable engineers for the sole benefit of the various industries in the locality, and for whose services no charge is made. Many heating problems are quickly solved by the industrial gas engineer due to his wide and varied experience. There is also maintained a stock of appliances and burners for industrial purposes, and these engineers are prepared to design and build special equipment when necessary.

One of the most common operations around a manufacturing plant is that of boiling large quantities of water, lye, or other cleaning solutions. There are various methods of doing this. Steam is most generally used for this purpose, either by means of a coil in the tank or exhausting the steam directly into the liquids. Sometimes steam is not available, especially in the smaller plants. To meet this condition there is the automatic gas-fired steam boiler built in units of 1 to 25 horsepower. Figs. 1 and 2.

These boilers are very compact and comply in every respect with the A. S. M. E. code and state inspection laws. They will automatically maintain a constant pressure. They usually have about three times as many tubes as the same capacity coal-fired boiler, and consequently a very much higher efficiency. The gas consumption averages about 75 cubic feet per horsepower hour of steam consumption.

In order to compute the weight steam required to raise a given

Acknowledgement is made to *Gas Age-Record* for the use of the cuts illustrating this paper.

A paper presented before a meeting of the Society. The author J. Weaver Smith, is industrial engineer, with the Citizens' Gas Co., Indianapolis, Ind.

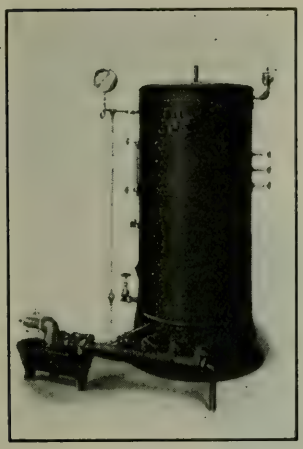


Fig. 1—Automatic Gas-fired Boiler

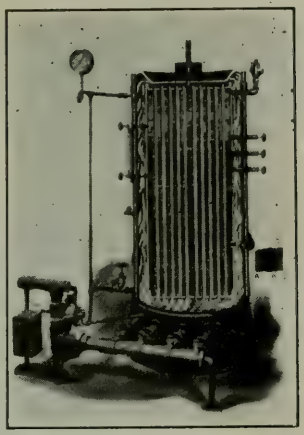


Fig. 2—Cross-Section of Automatic Gas-fired Boiler

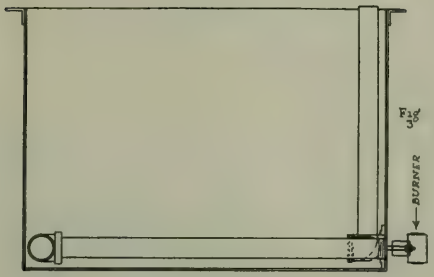


Fig. 3—Side View of Tank Heated by Internal Method

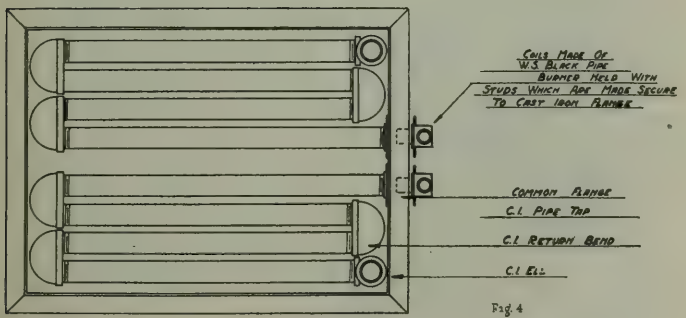

COILS MADE OF W.S. BLACK PIPE BUSHED HELD WITH STUDS WHICH ARE MADE SECURE TO CAST IRON FLANGE
COMMON FLANGE
C.I. PIPE TAP
C.I. RETURN BEND
C.I. ELL
Fig. 4

Fig. 4—Top View of Internally Heated Tank

volume of water to any given temperature, multiply the pounds of water to be heated by the difference of temperature between it and that to which it is to be raised, for a dividend; then to the temperature of the steam add 966.6 degrees Fahr., and from that sum take the required temperature of the water for a divisor; the quotient will give the weight of steam. The weight of one horsepower of steam is approximately 30 pounds. The flow of steam in pounds per second through a nozzle

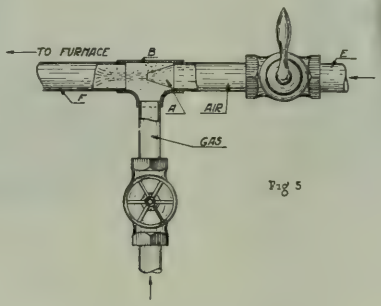


Fig. 5—Siphon Blast Mixing Tee

equals the absolute pressure in pounds per square inch by the area in square inches of the nozzle divided by 70.

Other methods are the uses of coal fires and oil burners under the tank. These are more or less objectionable due to lack of cleanliness, floor space, ease of operation, etc. Then, too, we have the method of placing gas burners under the tank. The author's observation has been that by burning the fuels under the tank, an efficiency of only 10 to 30 per cent is obtained. A much better method is what is known as the internal heating method, Figs. 3 and 4.

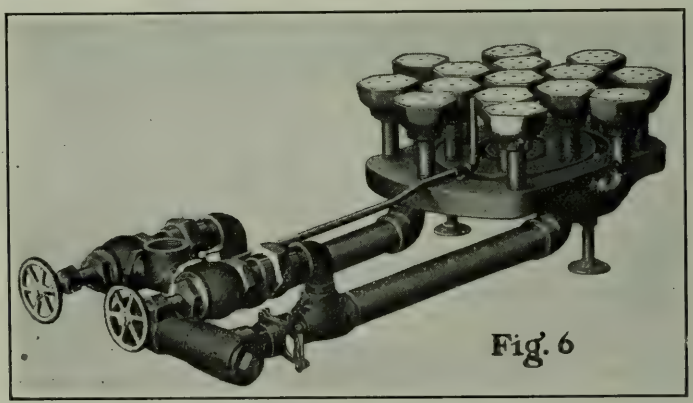


Fig. 6—Pyrogenetic Burner Group

This consists of the use of a coil of large size black iron pipe in the tank and resting on the bottom, one end projecting through the side or end of the tank, and the other end rising in the corner above the water level. A blast burner pointed directly into and placed about ¾

inches from the lower end of the coil, burns a high temperature flame within the coil and the heat is dissipated directly into the liquid. While the temperature of the flame on entering the coil may be about 1800 degrees Fahr., the temperature at the upper end of the coil is only about 150 degrees Fahr. Thus a very high efficiency is obtained. Not only

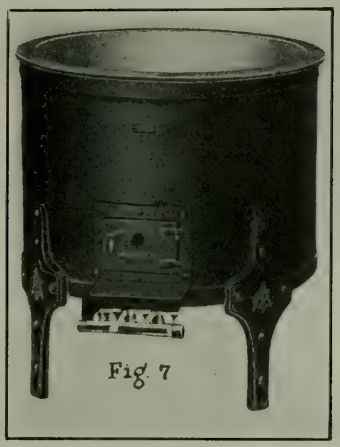


Fig. 7—Cauldron Furnace, Gas-fired

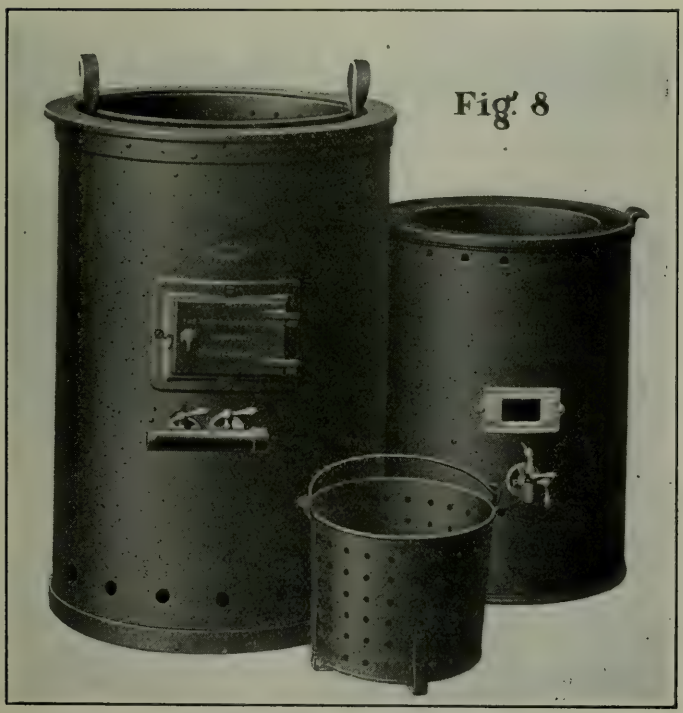


Fig. 8—Gas-fired Soda Kettles

this, but the liquid is brought to the boiling point very much more rapidly. In one instance this time was reduced from three hours to only twenty minutes. The amount of water boiled was approximately 165 gallons. Without taking into consideration the loss of heat through the walls of the tank and the top of the liquid, an efficiency as high as 95 per cent has been obtained. The loss of heat through the walls of the tank is from 10 to 12 B.t.u. per square foot of radiation per degree difference in temperature per hour. The loss of heat from the top of the liquid is in excess of this amount, probably 25 per cent more. With

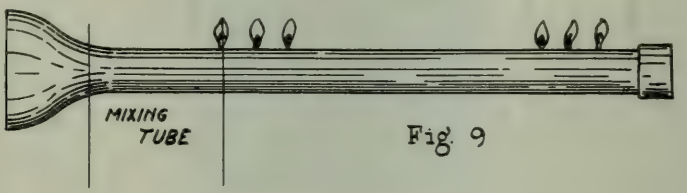


Fig. 9

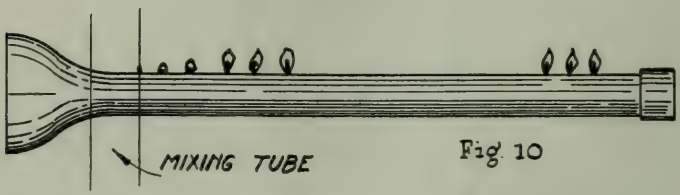


Fig. 10

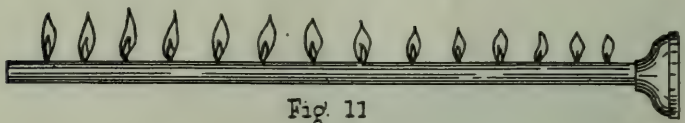


Fig. 11

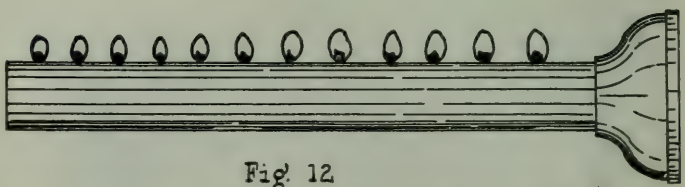


Fig. 12

Fig. 9—Pipe Burner with Proper Length of Mixing Tube. Fig. 10—Mixing Tube Too Short. Fig. 11—Burner Tube Too Small. Fig. 12—Burner Tube Too Large

large tanks holding 10,000 to 15,000 gallons or more, it is necessary to use two or more coils with a burner for each, so as to burn a sufficient amount of gas to provide the required amount of heat.

For the purpose of providing the proper mixture of air and gas and the consequent blast flame in this operation, the use of a premixing blower and burner nozzle is recommended, but never more than one burner nozzle to one premix, due to the explosive nature of the mixture and consequent danger from back fire.

Where the plant has a surplus of positive pressure air near at hand, the use of the siphon blast mixing tee in conjunction with a blast burner

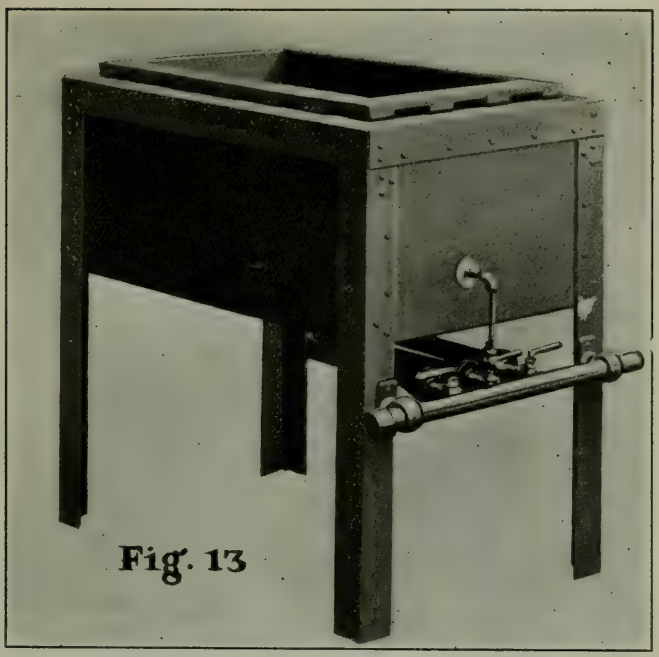


Fig. 13—Gas-fired Oil Tempering Furnace

nozzle, is recommended. The Zander burner has also been used successfully.

In this connection it might be well to state that the average man gives little or no thought to the use of the siphon blast mixing tee when constructing an appliance with blast burners. This is an exceedingly important detail, which, when overlooked, is generally a source of much annoyance and trouble.

As shown in the illustration, Fig. 5, the air coming from the supply pipe E at a pressure of ½ to 2 pounds per square inch, passes through nozzle A with a high velocity. This tends to form a slight vacuum in the mixing tee B, and the gas is drawn in from the side outlet of the tee. The air and gas then pass on together into the mixing tube F where they become thoroughly mixed, and thence to the burner. The essential features are the nozzle A which must project exactly one-eighth of an inch beyond the center of the tee, and the mixing tube F which must be of sufficient length to properly mix the air and gas.

Constructing Blast Burners

In designing and constructing blast burners it is well to remember the formula $Q = AV$, in which Q is the gas consumption, A is the area of the burner ports in square inches, and V is the velocity of the mixture of air and gas. Also that a velocity of more than 75 feet per second will blow the flame off the burner, and that a velocity of less than 25 feet per second will cause the burner to back-fire. Thus if we desire to

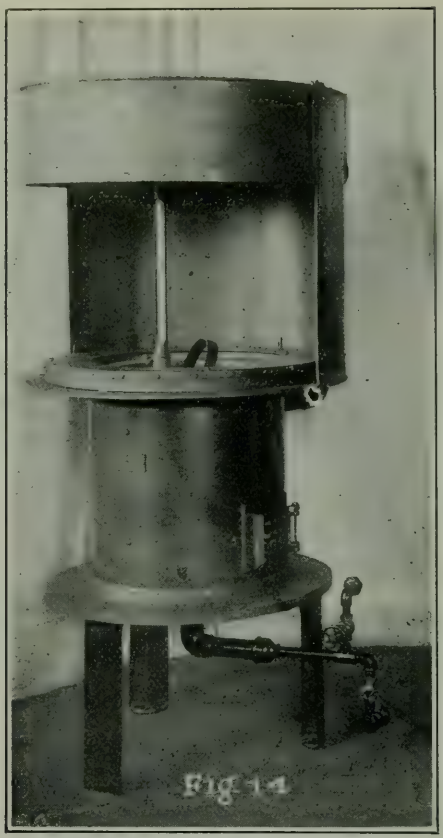


Fig. 14—Gas-fired Oil Tempering Furnace

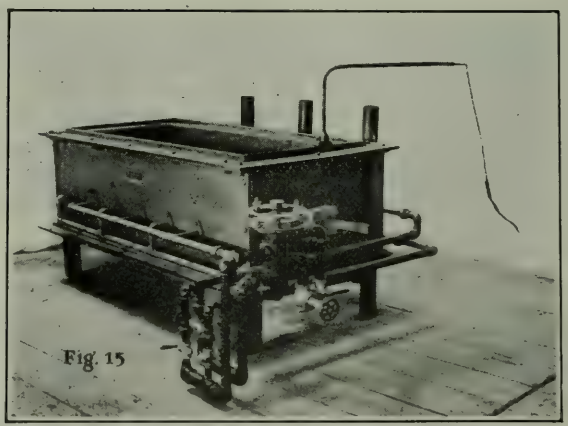


Fig. 15—Gas-fired Oil Tempering Furnace with Automatic Temperature Control

find the area of ports of a burner to consume 50 cubic feet of gas per hour with five parts air.

50 cubic feet = gas consumption
250 cubic feet = air consumption
75 feet per second = velocity

Then we have 300 cubic feet total consumption per hour divided by 3600 seconds, equals the consumption per second or 0.83 cubic feet. Substituting in the formula,

$$0.83 \text{ cubic feet} = A \times 75 \text{ feet}$$

$$A = \frac{0.83 \text{ cubic feet}}{75 \text{ feet}}$$

$$A = 0.011 \text{ square feet}$$

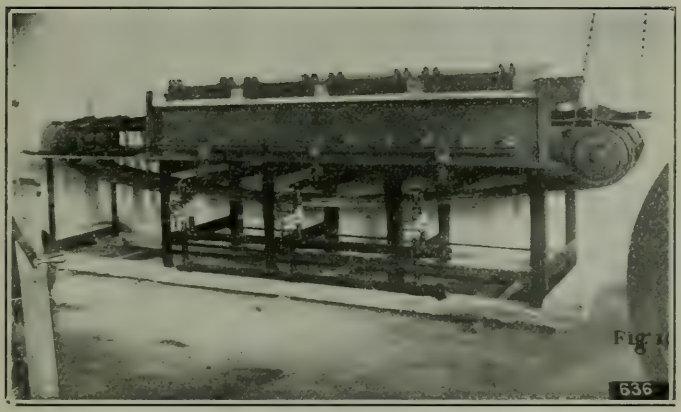


Fig. 16—Gas-fired Heating Machine for Tempering Agricultural Implements

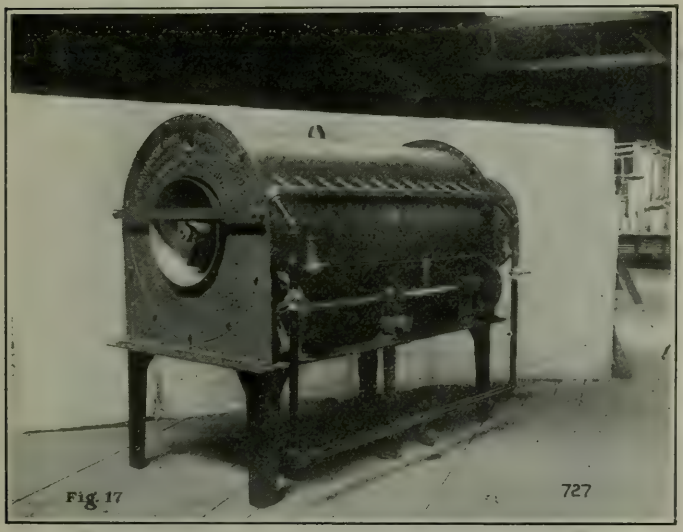


Fig. 17—Heating Machine for Sand Tempering or Coloring, Gas-fired

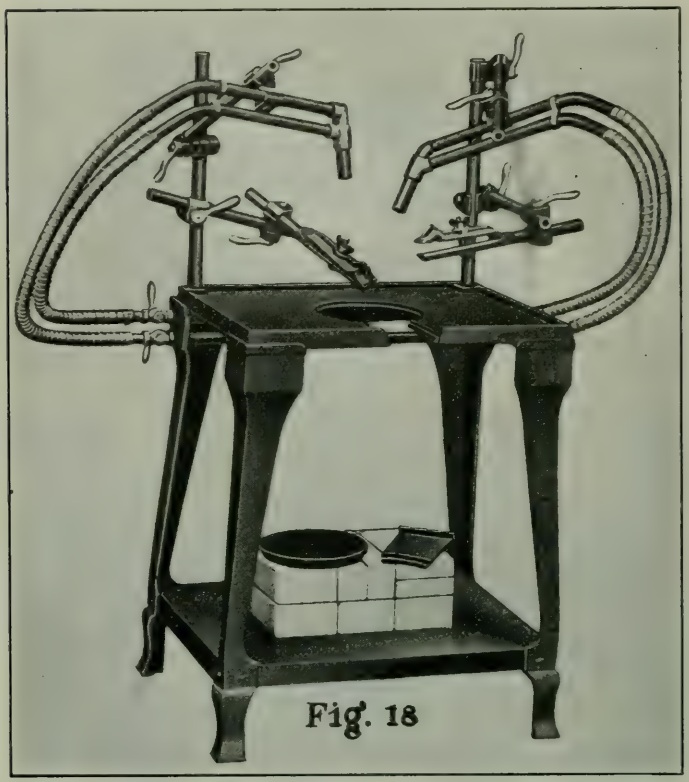


Fig. 18—Brazing Table Showing Arms for Holding Work, Gas-fired

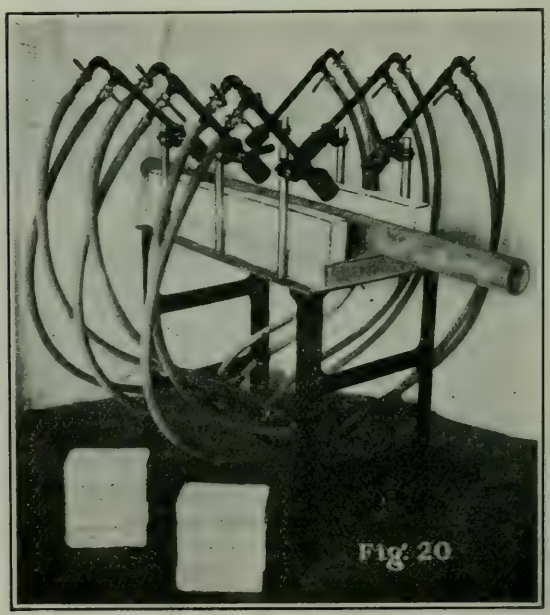


Fig. 20—Brazing Table for Brazing Pipe and Tubing

0.011 square feet x 144 equals 1.584 square inches or total area of ports. If four ports are desired, divide 1.584 square inches by 4 to find the area of one port.

Now to return to the subject of heating liquids for cleaning purposes, there are many places where only a few parts are to be cleaned and

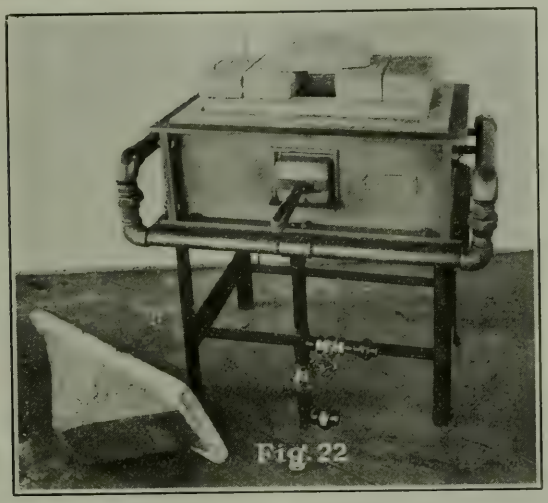


Fig. 22—Gas-fired Furnace for Dip Brazing

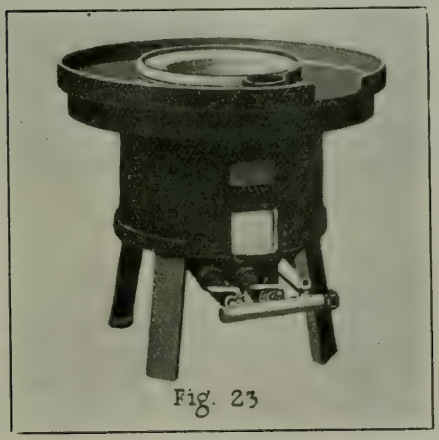


Fig. 23—Tinning Furnace with Pre-heater

the use of gasoline is objectionable. To meet this condition we have cauldron furnaces (Fig. 7) and soda kettles (Fig. 8) of various sizes up to 300 gallons capacity and heated by means of gas burners of the atmospheric mixer type and pyrogenetic type, Fig. 6.

These are much more efficient than home-made equipment due to better insulation and construction and are highly recommended. However, some plant managers are unwilling to pay the higher first cost for these appliances, and endeavor to get the same results from very crude home-made equipment. To them a few words regarding the proper de-

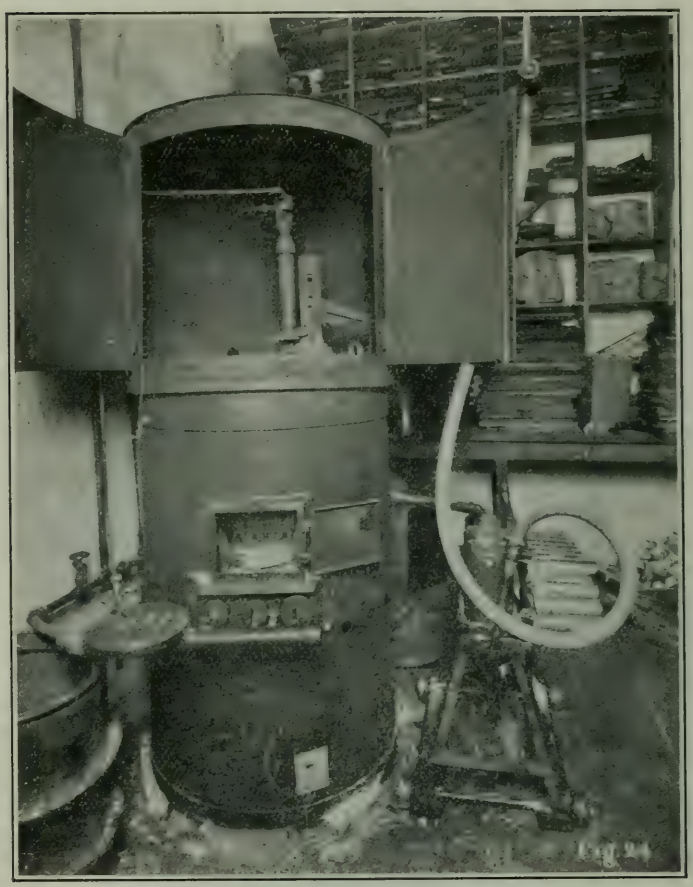


Fig. 24—Soft Metal Melting Furnace with Automatic Temperature Control

sign and construction of atmospheric type gas burners would not be amiss at this particular time.

Professor Bunsen of the University of Heidelberg noticed that when a draft of air strikes the surface of an open gas flame, the flame is reduced in size and becomes non-luminous; this suggested to him the idea of premixing a portion of the required air before combustion took place. The result of this was the reduction of the size of the flame and radiation losses due to the elimination of free carbon from the flame. Thus an increase in flame temperature resulted, and it is upon this last condition that the value of atmospheric burners depends for useful work, as a high flame temperature means a higher temperature in the products of combustion. It is important that high flame temperature be maintained for most industrial purposes.

In the design of an ordinary pipe burner, the first thing to know is the amount of gas you desire to burn so as to select the proper size pipe. The gas burning capacities of pipes are as follows:

Size of pipe:	⅜-in.	½-in.	¾-in.	1-in.	1¼-in.	1½-in.	2-in.
Cubic feet per hour	1-15,	5-25,	15-40,	25-60,	40-90,	60-140,	80-230.

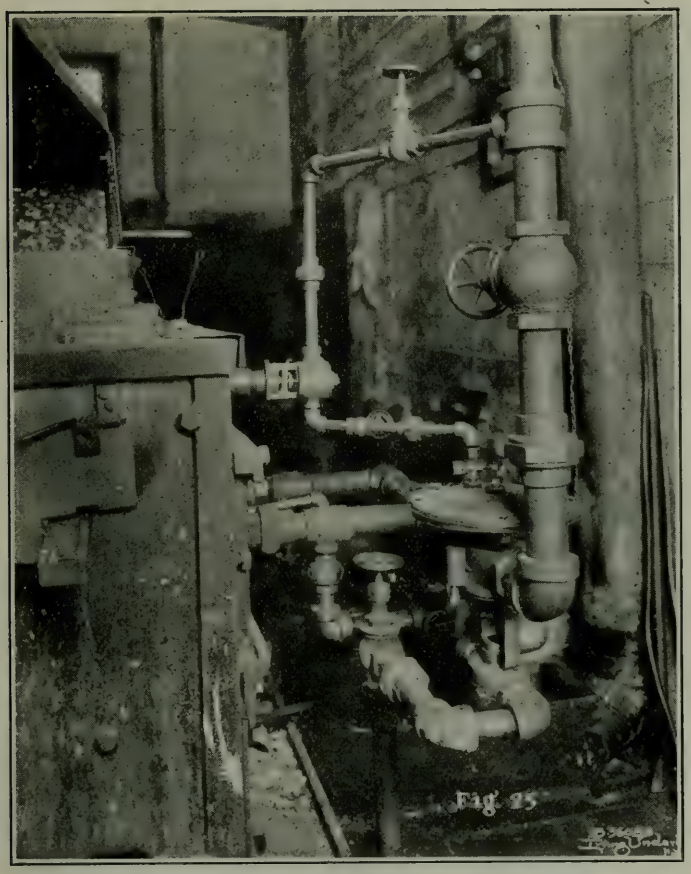


Fig. 25—Thermostatic Temperature Control for Blast Burners

The next thing to know is the length of the flame along the pipe. It has been found by experimentation that the proper spacing of the burner ports of the average burner should be one-third inch center to center. Now to find the number of ports, multiply the length of the flame by 3 and add 1 for the first port. Then to find the diameter of the drilled port, we note in the standard table of properties of wrought iron pipe, the internal area of the size pipe we have selected. From this figure should be deducted an allowance of 5 to 10 per cent to compensate for contraction or flow through small openings. The remainder divided by the number of ports will give us the area of each port.

Care should be taken to see that the first port is spaced not less than five times the diameter of the pipe, from the air mixer. This gives the air and gas a good chance to mix thoroughly before reaching the first port.

As to the size of gas orifice in the air mixer, this is obtained by reference to the standard table of drill sizes, diameters, circumferences, and areas.

Adjustable Air Shutters

As to the style of air mixer to use, either the conical face type or

the flat face type is satisfactory, but the latter type is preferable in most installations. In either case they should be equipped with adjustable air shutters. In order to function properly, these mixers must be me-

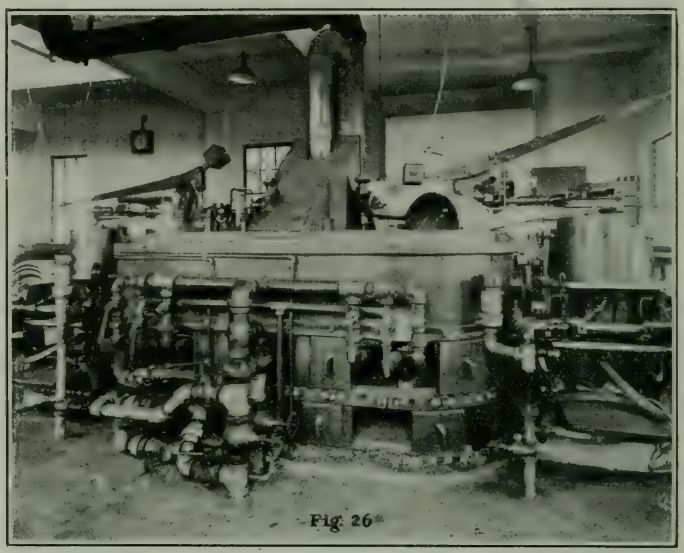


Fig. 26—Gas-fired Stereotyping Pot for Large Newspaper Offices

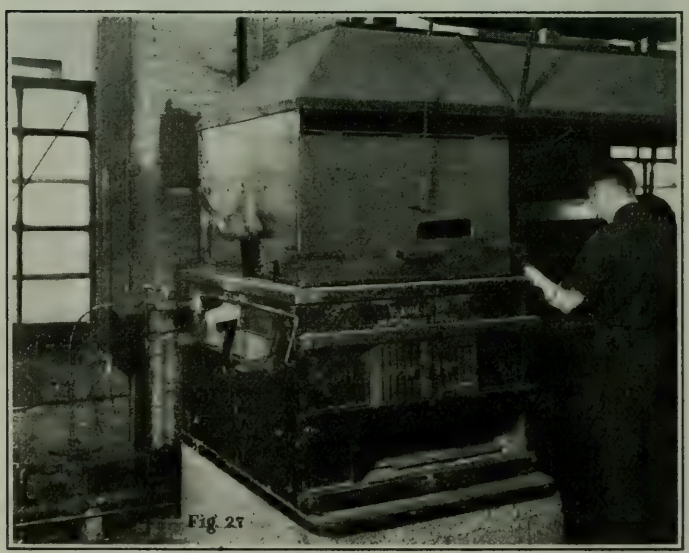


Fig. 27—Thermostatically Controlled Dross Melting Furnace

chanically perfect. It is therefore advisable to apply to your gas company for them where they are carried in stock.

The effect of using a pipe too small will be yellow and higher flames

Fig. 29—Gas-fired Water Still for Laboratory Purposes

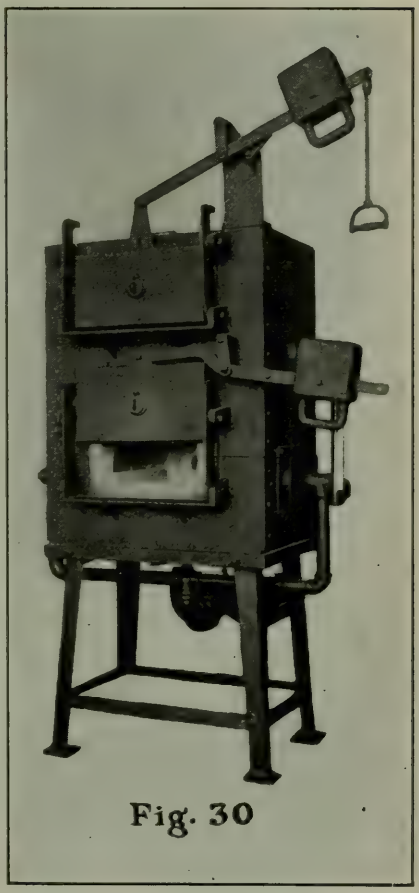


Fig. 30—Combination High-Speed Steel Heating Furnace with Pre-heater

especially at the rear end of the burner. On the other hand a pipe too large will produce flames that are small, round, and lifeless with very little heating value. In either case the efficiency is low. Fig. 9 shows pipe burner with proper length of mixing tube.

If the mixing tube (that part from the air mixer to the first port) is too short, (Fig. 10) the flames will be uneven and will hardly burn at the first few ports. Oftentimes it is impossible to prevent a back-fire.

If the mixing tube is too long, it will cause the gas to have a tendency to back out through the air shutters, and the flames at the burner ports will be yellow.

Under no circumstances should there be a bend or obstruction in the mixing tube.

The orifice in the air mixer must be exactly centered so as to give an even suction on the air. Otherwise a lazy, lifeless, yellow tipped flame will result.

If the burner ports are spaced too close, this will cause the flames

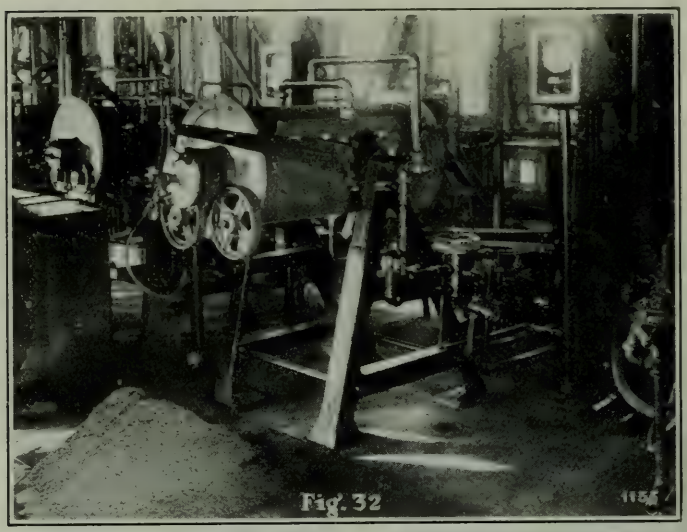


Fig. 32—Rotary Carburizing Furnaces Gas-fired. This Machine is Capable of Treating 75 Pounds of Screw Pins per Charge

to have a tendency to run together and smother, whereas, if they are spaced too far apart the flames will not catch readily and an explosion may result.

For drawing the temper of steel there is nothing better than an oil tempering bath, especially when the temperature is controlled by an automatic thermostat. As the maximum temperature desired is 600 degrees Fahr., the bath heated by gas is preferable owing to the ease of control. There are many efficient gas fired oil tempering furnaces on the market and several automatic temperature controllers.

Gas fired brazing tables shown in Figs. 18, 20 and 22, have a wider range of usefulness than any other heating appliance. By the aid of fire brick it may be readily converted into a forge or furnace for tool dressing, forming, bending, etc. The tables have many other uses, such as annealing brass or copper, sweating solder, heating rivets, and pre-heating for acetylene welding.

Next to the brazing table, the handiest gas appliance for heating operations is the gas-electric torch. This torch is a portable, self-contained unit consisting of a small electric motor blower with gas connection and burner nozzle. It is very light, weighing only a few pounds. Current for the motor is obtained from any electric light socket, and gas connection is made by means of a rubber hose. It is instantly adjusted to any position or angle and can be carried anywhere in one hand. Temperatures as high as 2500 degrees Fahr. are easily obtained with this torch. Its uses are many and varied, among them being the heating of ladles, the heating of an improvised furnace, for aluminum melting and soldering, for pre-heating in acetylene welding, and heating for bending, forming and straightening operations.

There are on the market today well designed and efficient furnaces which are gas fired, for tinning purposes and for soft metal melting of

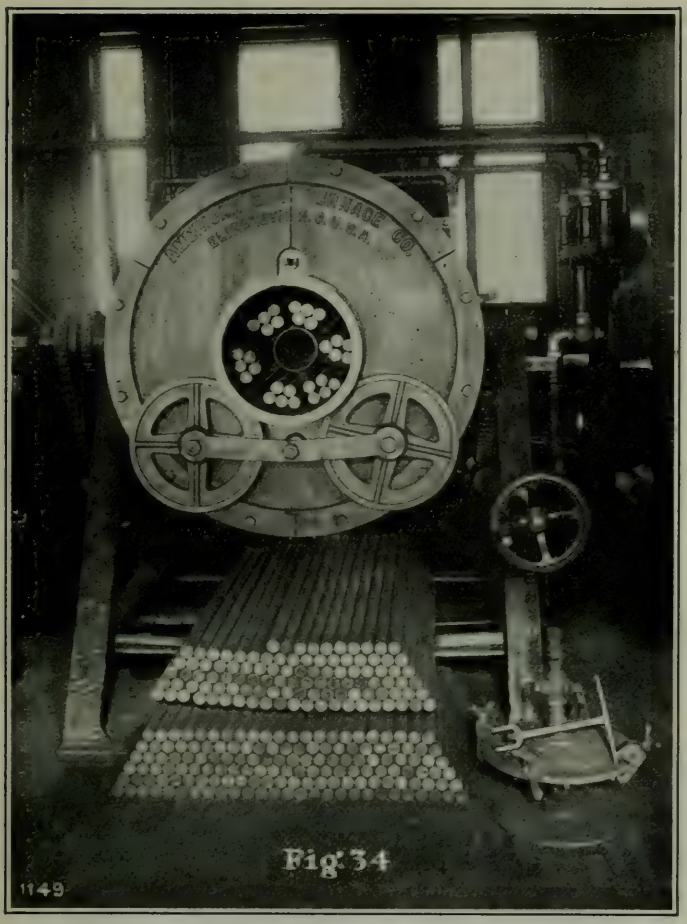


Fig. 34—Rotary Carburizing Furnace Showing Mine Car Axles in Furnace

all kinds. Fig. 24. A very considerable saving in metal is obtained by the use of automatic temperature controllers.

The oxy-acetylene torch is now almost universally used for welding and cutting, but it would be well to remember that city gas and oxygen can be and are used for cutting operations at about one-tenth the cost of oxygen and acetylene gas. The oxy-city gas torch has also been used successfully in certain welding operations of a limited nature. For lead burning purposes it is not excelled or even equaled.

Every well equipped laboratory requires pure distilled water. This is easily and quickly obtained from an automatic gas fired water still. These stills are supplied in capacities of one-half to ten gallons per hour. They are substantially and durably constructed and produce chemically pure distilled water since the steam is condensed in a tin lined copper tube. No revenue license is required as they cannot be used to distill spirits.

As to the heat treatment of high-speed steels, there are many designs of furnaces for different fuels in this work, but the writer is con-

fident that the results obtained with the combination gas furnace cannot be surpassed.

For the purpose of case hardening in quantity production, the use of the rotary gas fired carbonizing machine, Fig. 38, is most successful. This machine has a slowly revolving and properly heated cylindrical re-

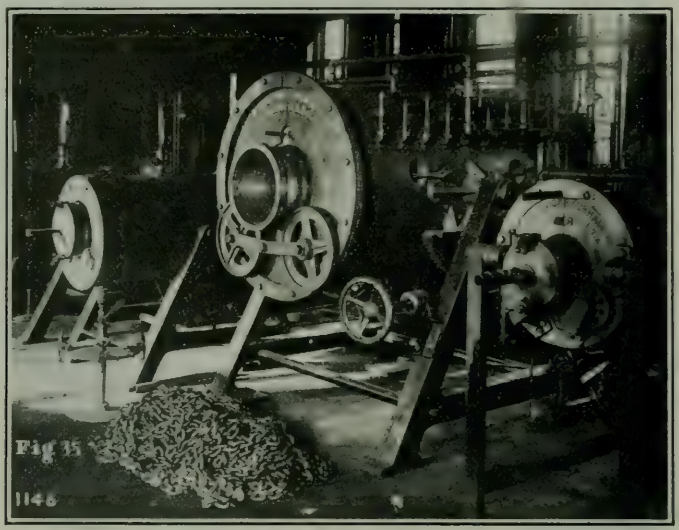


Fig. 35—Gas-fired Rotary Carburizing Furnace for Carburizing Chain

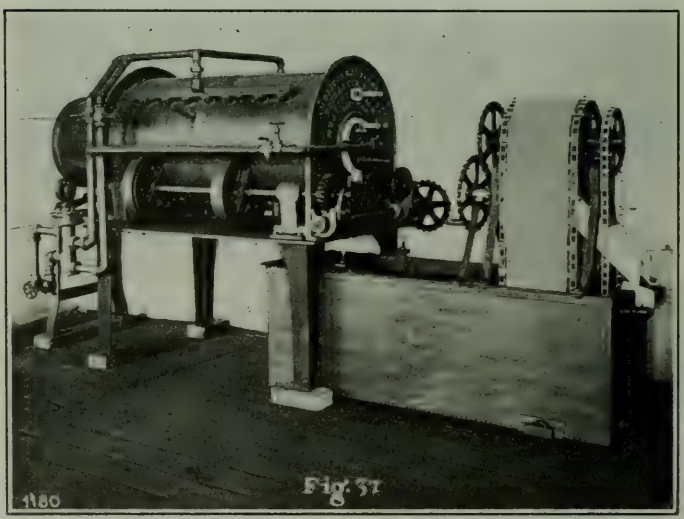


Fig. 37—Rotary Heating Furnace with Automatic Quenching Tank

tort which contains the work to be carburized. Originally city gas was injected into the retort under pressure, but a later method and more generally used is that of placing a small quantity of compound into the retort with the work. The heat rapidly converts this compound into gas and a pressure of about 65 pounds to the square inch is produced. These

machines are the fastest method of case hardening.

For heating operations such as blueing, tempering, and annealing in quantity production, the gas fired rotary heating machine is very desirable. Several types of heating, annealing and tempering furnaces are shown in Figs. 13, 35 and 37. These machines can also be fur-

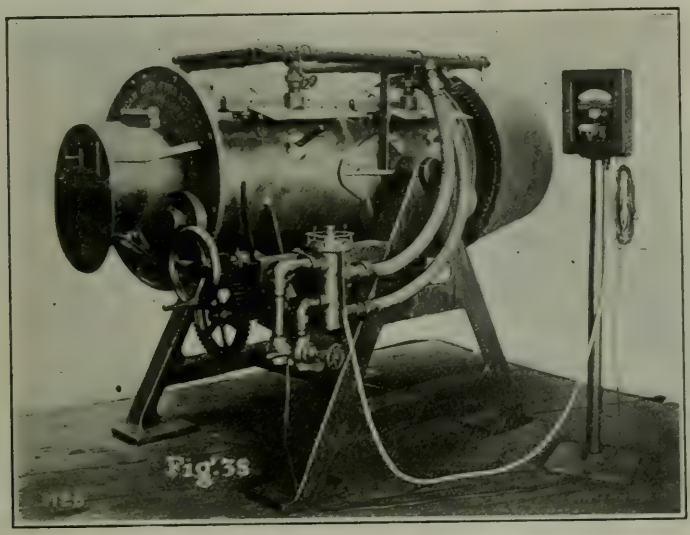


Fig. 38—Gas-fired Rotary Carburizing Machine

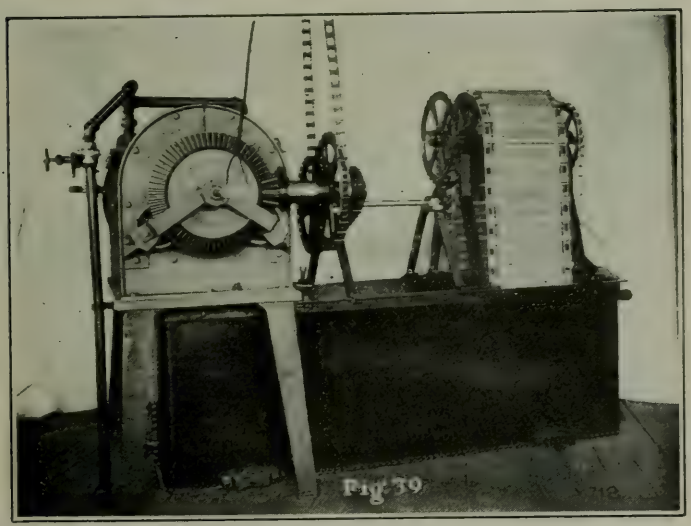


Fig. 39—Rotary Hardening Machine Equipped with Automatic Quenching Device

nished with automatic quenching tanks for straight hardening, Fig. 39.

One of the most efficient gas burners today is that with which temperatures up to 1800 degrees Fahr. may be obtained (Fig. 41 and 42) without the use of a blower. The secret of success of this burner is the patented orifice which maintains the highest possible velocity at the

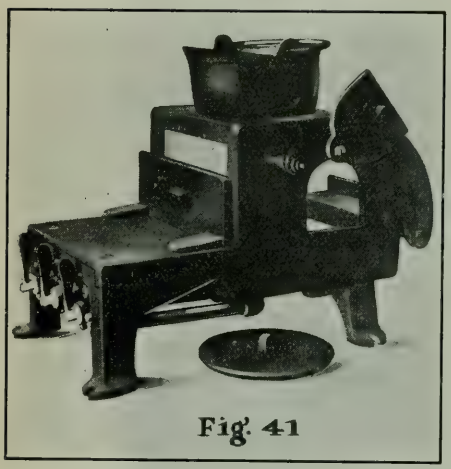


Fig. 41—Small Bench Furnace for Temperatures up to 1800 Degrees Fahr. No Blower Required

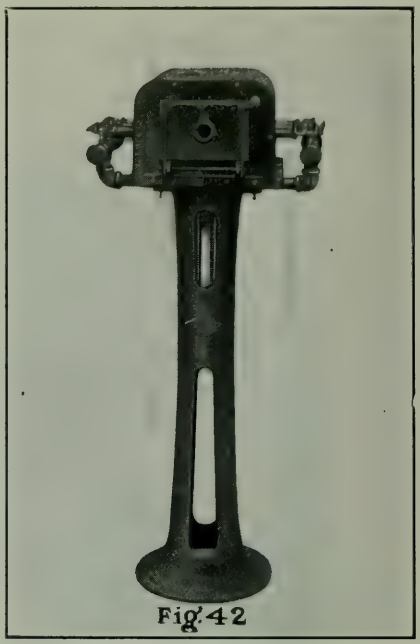


Fig. 42—Small Furnace for Temperatures up to 1800 Degrees Fahr. No Blower Required

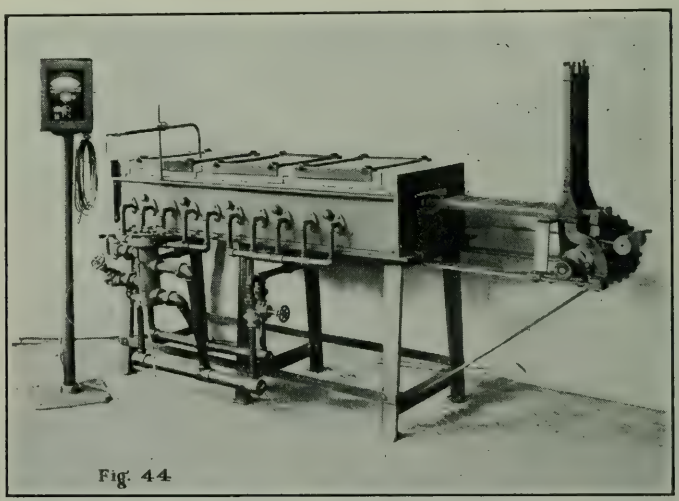


Fig. 44—Gas-fired Heating Furnace for Hardening Magnets

nozzle, directing the jet in correct alignment with the bunsen tube, and is instantly adjustable without departing from the direct jet principles.

It has been the author's observation that usually the millwright and plumber have no definite information or data but simply guess as to sizes of pipe, capacities, etc. This information is always available at the gas company, and their engineers are always ready to furnish any information or data that may be desired.

SOME FUNDAMENTALS OF RESEARCH

By F. O. Clements

Abstract

The fundamentals of industrial research are reviewed in this paper. It is pointed out that industry passes through several distinct cycles from its institution through its normal life and finally its decay. The life cycle can be prolonged indefinitely with properly directed and executed research yielding concrete results.

Research can be divided into three types. First—that of pure science, similar to the pure science research in the universities, which is concerned with the establishment of principles and fundamentals; second, finding the use for a fundamental fact is likewise research or duplicating the results of such researches can be termed commercial development; third, manufacturing developments are research activities involving new processes, new materials and frequently revolutionary methods of manufacture.

A general lack of knowledge of the problems involved in manufacturing is evidenced by the vast number of patents dealing with new inventions, most of which are valueless. Many are thoroughly practical devices, but entirely too complicated and costly to warrant utility value.

Prejudices of an investigator frequently hamper and influence his work to the detriment of the research. The author points out that an initial lack of knowledge of the problem under investigation is frequently an asset, as the investigator is then free from bias or first impressions and prejudice.

Industry Must Adapt Itself to Times

"INDUSTRY, in its simplest conception, is merely the transforming process, whereby natural resources are modified through a series of operations into commodities required to satisfy the needs of the community."

Industries, like the men who create them, have a life cycle: birth, period of development and growth, maximum power and decadence. The life cycle can be prolonged indefinitely if the industry has continuous growth through the acquisition, development and application of new knowledge. As we look back through history, we can see the working of natural law and, with this perspective can see that industry, just like the individual, must make adjustments to changes entirely outside of itself. Both men and industries fail because they have not been educated to identify or make use of facts.

Broadly speaking, the progress that has been made up to the present time, has been due to developments that are largely the outgrowth of necessity and invention. As in the case of the lumberman's forest, the finest and most accessible timber has been cut, for it was obviously worth while. The time has arrived when developments, garnered from every-day necessity and simple observation, no longer make progress. Failure to make adaptation

A paper presented at the Detroit convention, Research Symposium. The author, F. O. Clements, director of division of research, General Motors Research Corp., Dayton, O.

to the new developments perpetuates the lack of harmony, which, in time costs the industry its life. There is no standing still in the business world today.

Industry's Foundation Must Be Facts

Industry has become highly technical and complicated. It has assumed a bigness and a character that is endeavoring to change that cycle of growth, maximum power and decadence. To do this, a look into the vague future is necessary. Development and investigation along scientific lines offers a worth-while likelihood of procuring facts; and it is on the foundation of facts and not guesses or opinions that big lasting industry must build to survive at all.

Looking Ahead: Research

This look-ahead, demanding fresh subject matter or anticipation of tomorrow's law of service, has been termed *research*. Research laboratories are established for the purposeful seeking of new knowledge and the application of scientific methods.

We normally conceive of research as being technical and far removed from the routine of business. That is true only to the extent that it applies ways, means and methods, that science has developed, to observe, experiment, measure, verify and replace guesswork and opinions with facts. This age of skilled production has brought forth outstanding qualities in the human race to organize and carry through the thousands of complicated technical operations from the raw material to the finished product, designed for the well-being and comfort of humanity.

We have, through our intensive skilled manufacture, tied up the production brains on problems of today's or tomorrow's output, which requires the utmost in concentration and ability to carry through to meet time and competition.

Investigation: Research Activity

To give adequate attention to the investigation of new materials, new methods and the determining of *whys* and *wherefores* has made it necessary to bring together here and there in the industries other groups of trained skilled personnel. These groups are not satisfied that things *are*, without finding out *why* they are and *what* they will be. They have supplemented the foundry, forge, shop, mine and field with the chemical, electrical and physical laboratories, test racks, observatories, libraries and lecture rooms. Their problem has not so much to do with the production of today but with methods of utilizing waste, preventing failure and making a better product. Their contribution has to do with a better utility at a lower cost for today, tomorrow and all time. The solution of one problem today simply opens up new channels as a means of coping adequately with the dozen problems of tomorrow.

Three Kinds of Research

Every industrial laboratory concerns itself with three kinds of research:

Pure Science, similarly to pure science in the universities, is concerned with the establishment of principles and fundamentals. The worker in pure-science activities usually does not know—at least, does not know precisely—what end he will achieve. In this connection, if it be essential for an industry to insure its future by investing in an intensive study of its

problems, it surely is equally as essential that a research laboratory should explore the unknown and maintain a commanding position well ahead of the procession. Such a look-ahead should comprehend objectives, four or five years distant. Without pure science and its accumulated results, nothing can be intelligently applied. Finding the use for a fundamental fact is also research; duplicating the result can well be termed *commercial development*. So, in every well-organized research group, there is a division where ideas are analyzed for their conformance to pure-science fundamentals, as well as for their commercial requirements and practical production. As many of the research activities involve new processes, materials and even revolutionary methods of manufacture, it is also necessary to carry through in such instances initial *manufacturing developments*. This makes certain that all difficult processes and methods have been eliminated or simplified to fit in with practical methods of production. These last two functions of a research laboratory must not be permitted to interfere with the main objective, the collection of fundamental facts.

So a research group's activities consist, after all, of getting results by just plain hard work, intelligently directed and applied. Much of research work is a failure, due to the fact that few men can vision the future and the necessity involved in a useful device. We have examined untold hundreds of patents dealing with new inventions. Only a few were considered worthy of attention at all. Many were thoroughly practical devices but entirely too complicated or costly to warrant utility value. Others had no utility at all; still others were thoroughly impractical. There is altogether too much theorizing without knowing the problems.

Research: Self-Education

The job of a research laboratory is largely one of putting salt on the tails of ideas. The ancestor of every human action is a thought. Consequently, research problems are above all human problems. Research is, after all, self-education. One takes a problem and finds after sufficient self-education in the principles involved, that the solution is extremely simple. Close contact with the work at hand is essential. No one can understand the elements of a problem at long range. Reading reports and sitting in an easy chair at the end of a telephone will not answer. Our boys house with their work and get into the thick of the fray.

Prejudice and Opinions

The two great deterrents to successful research are prejudices and opinions. The first duty of a research organization is to collect facts and only facts. Engineering became worthy of credence only when definite and exact measurements took the place of guesses and wishes. It is one of the most difficult of tasks to separate one's self from opinions. Beecroft says, "It is akin to a medical operation in which we literally amputate what has become a corporate part of our daily existence. Research really becomes a work of upsetting your past life and building a new foundation upon which to survey the future and build." Industrial history is just a record of opposition and prejudice to new ideas and new methods.

"When anaesthetics were discovered, a storm of protest arose against their use. Again the stock ideas prevailed. Pain was God-given, it was said, and any attempt to alleviate it was an effort to thwart His will.

But a Scotch physician, Doctor James Simpson, who knew something about psychology as well as medicine, after long and bitter opposition, brought the startling innovation into harmony with the prevailing system of ideas by writing a pamphlet in which he said: 'My opponents forget the twenty-first verse of the second chapter of Genesis. It is the record of the first surgical operation ever performed, and that text proves that the Maker of the universe, before he took the rib from Adam's side for the creation of Eve, caused a deep sleep to fall upon Adam.' This recognition of the way in which the human mind acts won the day for anaesthetics.[1]"

When Ericsson asked for an appropriation to build the MONITOR; Fox, assistant secretary of the navy, and the naval board, condemned the idea. They said that the heavy armor would sink the vessel. Their opinions were organized and filed away. They would not even test them with arithmetic, as Lincoln wished them to do.

Morse spent 12 years during which, with his mind absorbed in one idea and yet wholly dependent for bread upon his profession as an artist, it was impossible to pursue art with the enthusiasm and industry essential to success. He was looked upon as an unforunate dreamer with a scientific toy, the electric telegraph.

Even the introduction of the telephone meant breaking through a firm wall of conservatism and opposition. Some were dubious as to its practicability. Others predicated a very limited market. When, in a group of men representing financial interests called together for interesting capital in the manufacture and sale of the invention, one impetuous youth of fifty, with the fire of vision in his eyes, smote the mahogany table and exclaimed: "Gentlemen, I can see the day when there will be 100,000 of these instruments in use in this country," his words caused consternation. "For God's sake, man," some one whispered, looking around to make sure that the door was closed. "Don't ever let that remark get outside these four walls. People will think us crazy." Today there are something like 12,000,000 telephones in use.

The bowmen of the Middle Ages resisted the introduction of the musket; the sedan-chair carriers would not allow hackney carriages to be used; the stage-coach lines attempted by all possible devices to block the advance of the railway; Arkwright, the inventor of the spinning-frame, was denounced as the enemy of the working-classes and his mill destroyed. So we could continue to narrate indefinitely. Today, we still have with us, just as strong as ever, the universal, apparently natural, prejudice against anything and everything radically different or new.

The Problem and Success

The most difficult of all questions in research is the selection of the task and the enlisting of proper co-operative effort, so that the whole organization may act effectively until the problem is solved. Good judgment in selecting the problems is paramount. Then, if the organization has men who are imbued with perseverence and enthusiasm, the result is certain. In many laboratories, failure is ofttimes caused by misdirected effort. One very large organization once built up a laboratory of considerable proportions without recognizing the limitations of their materials. They spent much money and time on a certain development without recognizing the fact that

1. Swift: Psychology and the Day's Work.

the material of which it was made was brittle when subjected to the cold, although quite ductile when hot; and yet the device was highly stressed and was to operate in both hot and cold climates. Failure to recognize this point wrecked this project. In all cases, the problem should be a fundamental one and the objective should be clearly visioned, although the way may be hidden and in doubt.

Initial Lack of Knowledge an Asset

Contrary to first impressions, ignorance of a problem is ofttimes an asset, instead of a detriment. In selecting our personnel, preference is always given to the man of sound judgment, without question intellectually honest, who will persevere until the very end. For a definite development, we often select a man totally ignorant of the subject under consideration. We consider his ignorance in that particular direction as a worthy adjunct of marked value. Why such an attitude? Because so many men, with ever so slight a knowledge of the subject, have prejudices so deeply founded that they are inclined to jump at conclusions and pronounce a certain desired end as being unattainable.

A man to avoid for research is a man with fixed opinions. A problem must be approached with an open mind or it will never meet with proper solution. No matter how able the mind, a man who will not work with others wholeheartedly retards progress and does more harm than good to any organization. All organizations have such men and they sometimes are most valuable; but usually for the most effective work they must be segregated from the balance of the organization and allowed to work alone.

Most of our engineers have had exceptional experience in industry. Men trained in practical production are of real value to a research organization, as they can see many by-products of research, particularly the pure science type, that in some instances have been of greater importance than the original objective.

It is desirable, yes necessary, to believe in a research man to the uttermost and to surround him with everything within one's power to foster his enthusiasm; for men never measure up to their best unless you manifest your confidence in them. Research activities must not be surrounded by red tape or hindrances that injure or destroy initiative and enthusiasm.

It is well to remember that the worth-while inventions that are permanent assets to civilization are the results of exhaustive work and not a flash out of the sky. The electric light was perfected only after years of close work. Over 6000 different vegetable growths were tested in order to find a suitable substance for the filament inside the glass tube. When Edison finally did finish the incandescent lamp, nobody would have it. They were afraid of it.

Typical Example of Research Development

A typical example of how research development is handled would be of interest, particularly as it shows that, after all, research as it is carried on today is a part of the every-day activity of industry, to build new or better products for tomorrow. Assume that the problem is to design a more satisfactory mechanical device than one already existing.

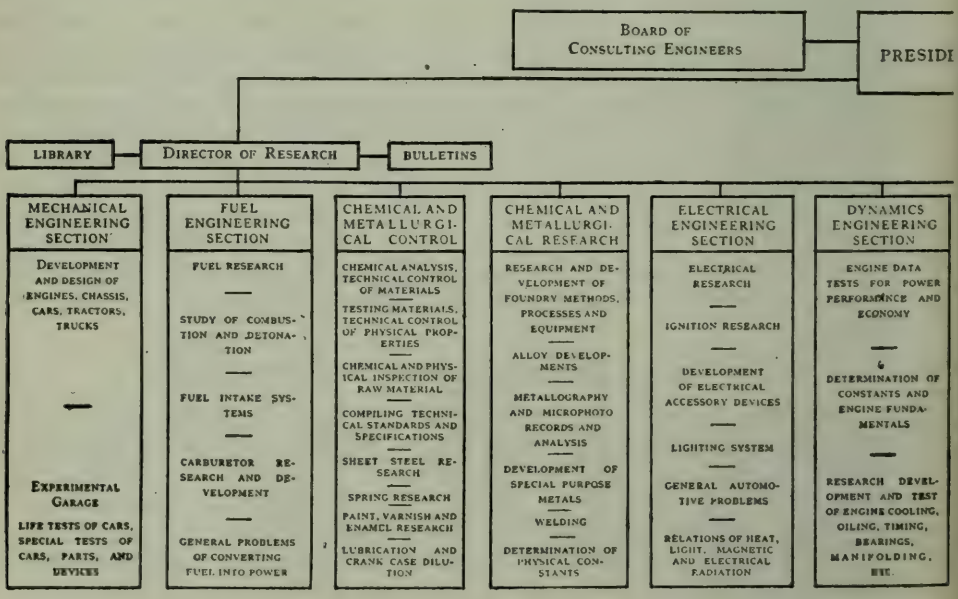
An engineer is assigned to this particular job. He is an average man of good mechanical experience and a fund of common sense. While willing

to work hard, he assumes the obligation with many misgivings, due to his ignorance of the device and its uses. Facilities, including the customary equipment of a laboratory, are given him. The research library immediately begins to comb the literature for items of interest in connection with the device or a similar utility and the patent department investigates the condition of the prior art, so that no effort will be misplaced.

The engineer's education on that particular problem begins. Possibly several similar devices, more or less satisfactory, are on the market. These are purchased and operated. Much observation follows, with definite recording of all experiments and facts. During this time, a species of specification is written visioning the objective to be reached. A picture of an ideal device, perhaps highly theoretical, is thus placed before the mind. Visioning the ideal is of great importance; for thoughts precede results.

The mechanisms are then subjected to mechanical analysis to determine efficiency. They are torn down, roughly sketched and measured for accuracy and named as to function. Assembly is made of the various components and a recheck made of the mechanical analysis to be certain that the assembly itself is correct and that the previous analysis was correct. The devices are again operated and very thorough data accumulated. Up to this time, not a single minute has been spent in designing the new equipment necessary to meet the ideal; in fact, little money has been spent and all of that for education. The result is that we have a man in charge of the work who has a very thorough knowledge of the fundamentals that pertain to that particular job.

Progress reports have been filed and, as a result, the laboratory possesses a volume or two that give definite facts. In this connection, the definite recording of failures or negative results are just as important as the recording of successes. Without much delay, the problem blossoms into the design stage. There has been no 'hit and miss' or wishbone type of design,


BOARD OF CONSULTING ENGINEERS
PRESIDI
LIBRARY
DIRECTOR OF RESEARCH
BULLETINS
MECHANICAL ENGINEERING SECTION
DEVELOPMENT AND DESIGN OF ENGINES, CHASSIS, CARS, TRACTORS, TRUCKS
EXPERIMENTAL GARAGE
LIFE TESTS OF CARS, SPECIAL TESTS OF CARS, PARTS, AND DEVICES
FUEL ENGINEERING SECTION
FUEL RESEARCH
STUDY OF COMBUSTION AND DETONATION
FUEL INTAKE SYSTEMS
CARBURETOR RESEARCH AND DEVELOPMENT
GENERAL PROBLEMS OF CONVERTING FUEL INTO POWER
CHEMICAL AND METALLURGICAL CONTROL
CHEMICAL ANALYSIS, TECHNICAL CONTROL OF MATERIALS
TESTING MATERIALS, TECHNICAL CONTROL OF PHYSICAL PROPERTIES
CHEMICAL AND PHYSICAL INSPECTION OF RAW MATERIAL
COMPILING TECHNICAL STANDARDS AND SPECIFICATIONS
SHEET STEEL RESEARCH
SPRING RESEARCH
PAINT, VARNISH AND ENAMEL RESEARCH
LUBRICATION AND CRANK CASE DILUTION
CHEMICAL AND METALLURGICAL RESEARCH
RESEARCH AND DEVELOPMENT OF FOUNDRY METHODS, PROCESSES AND EQUIPMENT
ALLOY DEVELOPMENTS
METALLOGRAPHY AND MICROPHOTO RECORDS AND ANALYSIS
DEVELOPMENT OF SPECIAL PURPOSE METALS
WELDING
DETERMINATION OF PHYSICAL CONSTANTS
ELECTRICAL ENGINEERING SECTION
ELECTRICAL RESEARCH
IGNITION RESEARCH
DEVELOPMENT OF ELECTRICAL ACCESSORY DEVICES
LIGHTING SYSTEM
GENERAL AUTOMOTIVE PROBLEMS
RELATIONS OF HEAT, LIGHT, MAGNETIC AND ELECTRICAL RADIATION
DYNAMICS ENGINEERING SECTION
ENGINE DATA TESTS FOR POWER PERFORMANCE AND ECONOMY
DETERMINATION OF CONSTANTS AND ENGINE FUNDAMENTALS
RESEARCH DEVELOPMENT AND TEST OF ENGINE COOLING, OILING, TIMING, BEARINGS, MANIFOLDING, ETC.

which too often interferes with effective and economical work. The mechanical analysis showed the losses in order of importance. Thus the research engineer has established yardsticks from which to measure conclusions and he knows where to concentrate effort.

Our experience has been that the most difficult part of any development is to understand clearly the problem ahead; in fact, one of the axioms of our organization is *a problem thoroughly understood is always fairly simple.*

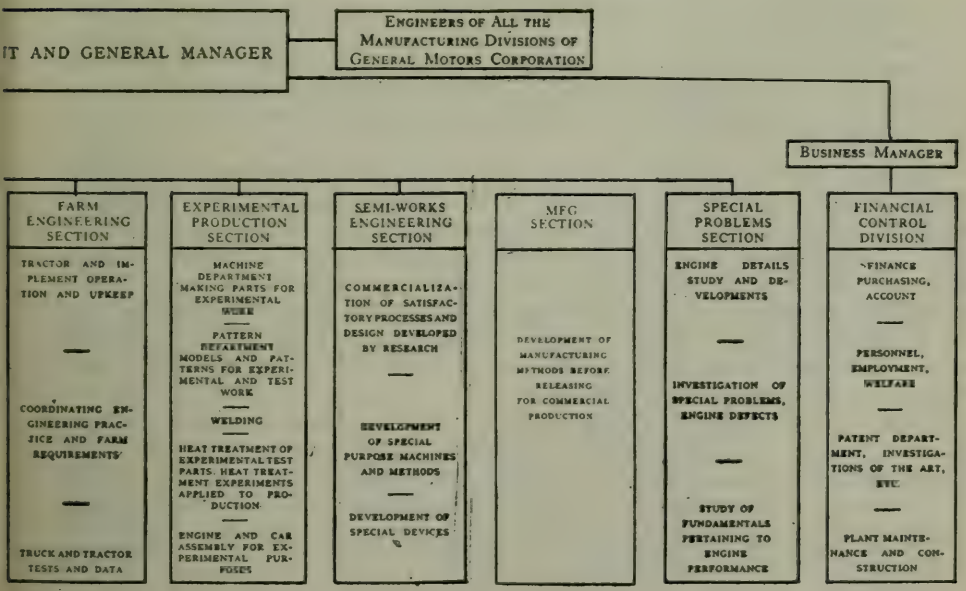
Scientific research must be untrammeled and free from restraint. The laboratory budget should always include an allowance to permit immediate tryout of new ideas that seem to have promise. If, with tinsnip-soldering-iron-methods, the worth of the idea is demonstrated, the work can then be accepted as a major project and a definite appropriation provided. For a new project to assume major importance, its merit and utility must be proved unqualifiedly by analysis and it must represent a real need of the world from the standpoint of either a new, lower-priced or better product.

Definite Standards

It is customary with us not only to vision the ideal but also to set a price to be met in production and establish a yardstick of what performance should be. It is always well to design with a high degree of quality in mind. If the price bogie will not permit such an expenditure, it then becomes necessary to study the offending detail intensively, so as to lower the cost and still retain the quality. These three things are of very great importance and must be clearly recognized prior to expending effort and time on the initial design. They sound trite but really furnish the compass that not only steers the investigation in hand to a successful outcome but largely determines the growth of the organization as a research staff worth while.

Definite organization, detailing problems and functions, is necessary, of

(*Concluded on Page* 429)


IT AND GENERAL MANAGER
ENGINEERS OF ALL THE MANUFACTURING DIVISIONS OF GENERAL MOTORS CORPORATION
BUSINESS MANAGER
FARM ENGINEERING SECTION
TRACTOR AND IMPLEMENT OPERATION AND UPKEEP
COORDINATING ENGINEERING PRACTICE AND FARM REQUIREMENTS
TRUCK AND TRACTOR TESTS AND DATA
EXPERIMENTAL PRODUCTION SECTION
MACHINE DEPARTMENT MAKING PARTS FOR EXPERIMENTAL WORK
PATTERN DEPARTMENT MODELS AND PATTERNS FOR EXPERIMENTAL AND TEST WORK
WELDING
HEAT TREATMENT OF EXPERIMENTAL TEST PARTS. HEAT TREATMENT EXPERIMENTS APPLIED TO PRODUCTION
ENGINE AND CAR ASSEMBLY FOR EXPERIMENTAL PURPOSES
SEMI-WORKS ENGINEERING SECTION
COMMERCIALIZATION OF SATISFACTORY PROCESSES AND DESIGN DEVELOPED BY RESEARCH
DEVELOPMENT OF SPECIAL PURPOSE MACHINES AND METHODS
DEVELOPMENT OF SPECIAL DEVICES
MFG SECTION
DEVELOPMENT OF MANUFACTURING METHODS BEFORE RELEASING FOR COMMERCIAL PRODUCTION
SPECIAL PROBLEMS SECTION
ENGINE DETAILS STUDY AND DEVELOPMENTS
INVESTIGATION OF SPECIAL PROBLEMS, ENGINE DEFECTS
STUDY OF FUNDAMENTALS PERTAINING TO ENGINE PERFORMANCE
FINANCIAL CONTROL DIVISION
FINANCE PURCHASING, ACCOUNT
PERSONNEL, EMPLOYMENT, WELFARE
PATENT DEPARTMENT, INVESTIGATIONS OF THE ART, ETC.
PLANT MAINTENANCE AND CONSTRUCTION

THE HEAT TREATMENT OF CAST STEEL FOR HYDROELECTRIC POWER MACHINERY

By B. Egeberg

Abstract

Norway is one of the foremost countries in hydroelectric power development. They have become experienced in the production of machinery for this purpose which will stand up under the conditions of operation which are required of it.

The author outlines the specifications usually used in ordering steel castings for hydroelectric power making. These specifications include the chemical composition, physical properties and thermal treatment. It is pointed out that the specifications are quite exacting although not too much so inasmuch as they can be complied with through proper thermal treatment when the steel is uniform in composition and sound in structure.

THIS paper dealing with the material used in hydroelectric power machinery in Norway may be of some interest, inasmuch as Norway is one of the countries which has taken a leading part in the utilization of water power.

The turbines, the pelton disks, shovels, trottle-valves, valve-housings, etc., from the smallest to the largest ever made in any country, are all made of electric cast steel. Inasmuch as the damage that a break down of any part, would produce would be tremendous, the material specifications are very strict, and usually are as follows:

Tensile strength: 60,000 to 70,000 pounds per square inch
Yield point: 34,000 pounds per square inch (not always required)
Elongation in 2 inches: minimum 30 per cent
Reduction in area: minimum 45 per cent
Charpy impact: up to 8 kilogram meters per square centimeter (with charpy pendulum small size; test bar 10 x 10 millimeters 100 millimeters long and notched as in sketch Fig. 1.)
The microscope shall show a fine, rounded grain and the carbon shall be evenly distributed. No welding of cavities and blow holes is permitted. The specifications are to be fulfilled by annealing.

Probably the required impact figure will be the difficult part of the specification. The work of 8 kilogram meters approximates 58 foot pounds and by way of comparison, a nickel chromium steel for casehardening purposes (C .13 to .15, Cr 1.00, Ni 4.00) hardened in oil from 870 degrees Cent. and tempered at 650 degrees Cent. and then cooled in oil, will give a charpy impact figure of 13 to 14 kilogram meters per square centimeter. As will be shown later, an impact toughness as high as 12 kilogram meters per square centimeter is in some cases obtained on castings, which have been subjected to the adopted heat treatment.

To obtain the required impact number, the steel must be mild (usually .18 to .22 per cent carbon) pure and free from any defects and must be poured at a low temperature; the last item is of great importance especially for big castings, as hot pouring of such will produce large dentrites causing

A paper written for TRANSACTIONS. The author Dr. Birger Egeberg, is metallurgist, the Stavanger Electro-Staalverk, Stavanger, Norway.

trouble in heat treating. A typical melt analyzed C .20, Mn. 63, P. 020, S .012, Si .25, no alloy being used. The regular cast condition is seen in Fig. 2 taken from a pelton disk weighing 6000 kilograms.

As every big casting and every set of smaller ones cast together (linked together) is to be tested by the customer's inspector, the castings are always furnished with attached coupons about 30 x 40 millimeters in section and 300 millimeters long, which are drilled or sawed off after the final heat treatment has taken place. Additional coupons are preliminarily tested in the laboratory, so that every casting put before the inspector is sure to pass inspection. As a guide for the heat treatment to be undertaken there is produced from every melt a sufficient number of fractures which shows the grain as cast.

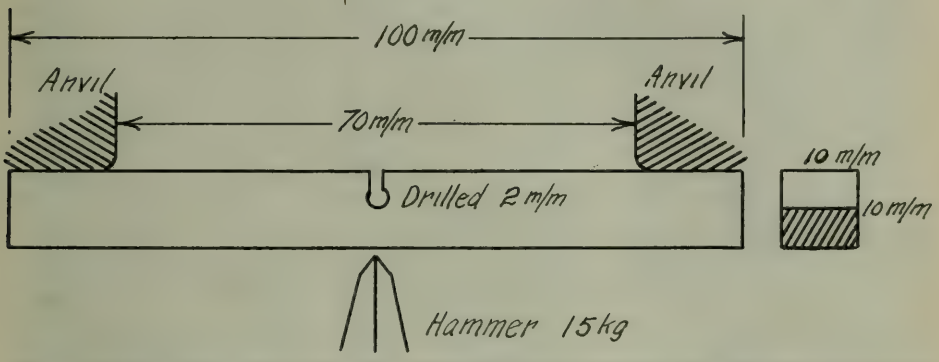


Fig. 1—Sketch of Charpy Impact Test Bar, Showing Method of Supporting and Fracturing the Specimen

First Heat Treatment

Castings weighing up to 8 tons are treated in an electric annealing furnace, larger castings in an 80-ton furnace heated with producer gas. Both furnaces are controlled by pyrometric regulators. The electric furnace is very well adapted to exact working but will, like other furnaces, cool down much too slowly for the purpose, as a more rapid cooling from the annealing temperature to about 650 degrees Cent. is essential in order to meet the specifications. Opening the door gives uneven cooling, and the pulling out of the car type bottom is not to be recommended on account of the danger of warping. The castings for hydroelectric power machinery are usually of an intricate shape, and therefore liable to warp if not cooled evenly. The furnace has therefore been equipped with air inlets in the roof, connected to a strong blower having large air volume and low pressure. By this arrangement the steel can be cooled down to below the critical point Ar^1 in a comparatively short time.

The heat treatment of the larger castings in the gas-fired furnace is conducted along the same lines. The gas enters through inlets in the roof and the air through additional openings. Every gas inlet has its own air inlet. Cold air from a blower is used. The furnace is lighted with a long burning stick brought up under the roof, or through a fire lit on the car bottom. The cooling down of the castings is accomplished as in the electric furnace.

The annealing temperature is in most cases 900 degrees Cent. (1650 de-

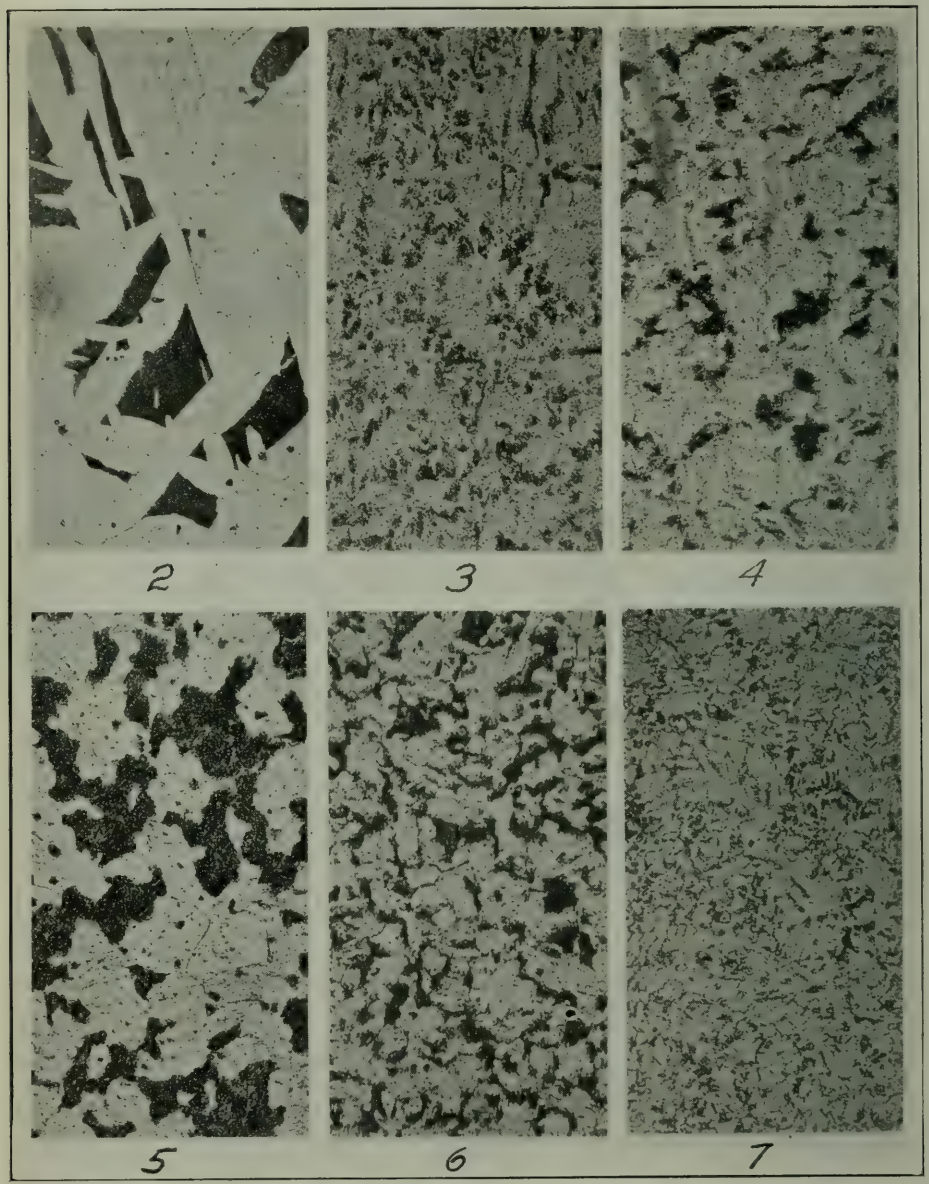


Fig. 2—Ordinary Structure of a 6-Ton Pelton Disc as Cast. Fig. 3—Structure of a 200-Kilogram Casting. It Showed a Charpy Impact of 12 Kilogram Meters per Square Centimeter. Fig. 4—Structure of an 8-Ton Casting Heat Treated Like Specimen in Fig. 3 Showed an Impact of 9 Kilograms per Square Centimeter. Fig. 5—Showing Excessive Grain Size. This Specimen Showed an Impact of 6 Kilograms per Square Centimeter. Fig. 6—Taken from a 7-Ton Casting. Fig. 7—Taken from a 200-Kilogram Casting Each Showing 9 Kilograms per Square Centimeter Impact

grees Fahr.) which temperature is held for a period of 4 to 10 hours (depending upon the size of the castings) and is then allowed to cool until black. The furnace is again raised to 650-700 degrees Cent. (1200-1290 degrees Fahr.) well below the Ac^1 point, the exact temperature depending upon the carbon and manganese content of the pieces under treatment, and held there for a period of 4 to 6 hours. The castings are then allowed to cool with the furnace. It should be noted that the given time-temperature intervals do not in all cases include the time necessary for the heat to penetrate the castings. It is quite noticeable that steel heat treated even in this mild way will become much tougher than steel cooled slowly in and with the furnace.

The object of the first treatment is:

1. To destroy ingotism
2. To impart to the steel as fine a grain as possible, because with a large grain, the required impact figure is not obtained, even where the ingotism is perfectly eliminated. The annealing temperature must therefore not materially exceed 900 degrees Cent. as the writer's experience, contrary to that of some other investigators, is that a higher temperature will influence the impact figure.

Coarse Grained Fractures Undesirable

Excluded castings where the fracture in the cast condition showed too coarse a grain, and further excluding castings weighing more than about 8 tons, the described process will give products of which about 2/3 will pass the preliminary laboratory tests. Figs. 3 and 4 respectively show the structure of a 200-kilogram and an 8-ton casting treated in this way. The casting illustrated by Fig. 3 gave an impact toughness of 12 kilogram meters per square centimeter, and the other 9 kilogram meters per square centimeter. These preliminary tested pieces are placed before the inspector or shipped with the attached coupons. The remaining 1/3 of the castings will, in most cases, fulfill the specifications excepting that of the impact figure. These are observed under the microscope in order to discover any dangerous arrangements of slag-inclusions, ingotism, etc. Fig. 4 shows the structure of a big casting which has undergone the described heat treatment, and which did not show the required impact figure, all other parts of the specifications being fulfilled, i. e.

Tensile strength	64,000 pounds per square inch
Yield point	35,000 pounds per square inch
Elongation in 2 inches	33 per cent
Reduction in area	58.8 per cent
Charpy impact	6 kilogram meters per square centimeter

The static tests are very satisfactory but the impact figure being 2 kilogram meters per square centimeter too low. The casting had to be treated once more on account of excessive grain size and slight carbon segregation, in order to obtain the necessary impact toughness. This gives an idea of the very rigid requirements which some manufacturers of hydroelectric power plant machinery are specifying. It is not the place here to discuss the value of such specifications, however it will only be mentioned that there is a tendency to go down to 6 kilogram meters per square centimeter impact figure.

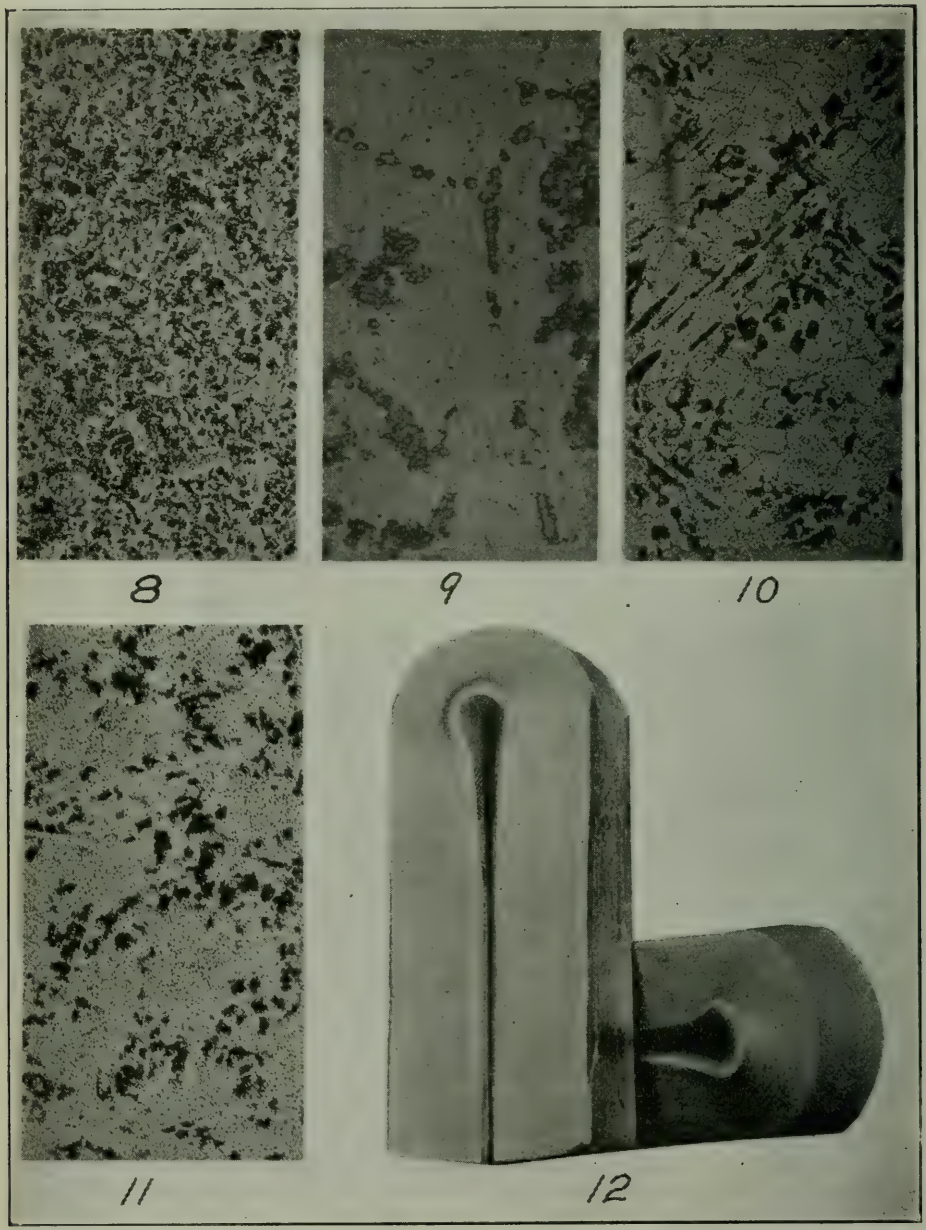


Fig. 8—Shows the Structure of a Specimen Which Showed an Impact of 3 and 5.15 Kilograms per Square Centimeter. Fig. 9 X 500—Shows Sulphide Slag Inclusions Forming Continuous Lines. Same as Fig. 8. All Specimens X 100. Fig. 10—Specimen Showing Traces of Cast Structure Which Gave an Impact of 5 Kilograms per Square Centimeter. X 100. Fig. 11—Imperfectly Annealed Specimen Showing a Charpy Impact of 8 Kilograms per Square Centimeter. X 100. Fig. 12—Bend Test Made on Specimen Fig. 11

Second Heat Treatment

The 1/3 of the castings not fulfilling the requirements but showing no other defect than excessive grain size, (Fig. 5) are heated once more for a short time to nearly 900 degrees Cent., but long enough for the heat to penetrate to the interior of the castings and refine the grain, they are then immediately cooled down to black. Then follows the low temperature treatment at 650 to 700 degrees Cent. as before. Typical photomicrographs are shown illustrating the various structures resulting from different heat treatments.

After the second treatment, if perfectly conducted, the castings will show a structure as represented by Figs. 6 and 7 taken from a large 7-ton and a small 200-kilogram casting respectively. If the steel is pure and good, it will in this condition give an impact number of 8 kilogram meters per square centimeter and more. On the other hand, if the steel is not good, no heat treatment as specified here will bring the impact toughness up to what is required. Fig. 8 shows the microstructure of such a casting weighing about 2 tons after the second heat treatment. The grain is very close and the cast structure is perfectly destroyed, so evidently the heat treater is not to be blamed for the fact that the steel showed an impact number of 3 and 5.15 kilogram meters per square centimeter. The variation in the figures indicates that something is wrong, as otherwise the results in good steels are more constant. Fig. 9 at 500 diameters magnification shows sulfide slag inclusions forming dangerous lines of weakness. This condition accounts for the low toughness and also for the variations in impact values inasmuch as these may occur depending upon whether few or many of these slag lines are present on the notched spot of the test-bar. It is noticeable that a steel with a considerable amount of finely distributed inclusions tends to a closer grain than does purer steel. Furthermore slight traces of the cast structure influences the toughness and prevents the required impact figures from being obtained. Fig. 10 shows the structure in such a steel giving 5 kilogram meters per square centimeter charpy impact figure. After the second heat treatment the figure was 8.7 kilogram meters per square centimeter and the microstructure is shown on Fig. 11, showing a peculiar arrangement of the pearlite along lines surrounding the ferrite. The same is more often to be found in higher carburized materials and is supposed to represent an intermediate state in castings not perfectly annealed. If not very pronounced it will impart to the steel satisfactory strength and toughness, the casting demonstrated by photomicrograph, Fig. 11 gave cold bend tests ¾ x 1 inch as shown in Fig. 12.

Larger castings weighing more than about 8 to 12 tons and pieces cast with an excessively coarse fracture almost always require the second heat treatment, which in these cases is undertaken at once, the first treatment being sometimes conducted on a slightly higher temperature, as the complete destroying of ingotism only is aimed at.

The program in this case will be:

1. Heat to 900-950 degrees Cent.
2. Hold at this temperature for 4 to 10 hours according to the weight and thickness of the castings and the size of the truckload.
3. Cool down till black.
4. Heat to nearly 900 degrees Cent. till the steel is heated through.

5. Blow down till black.
6. Reheat to 650 to 700 degrees Cent.
7. Hold at this temperature for 4 to 6 hours.
8. Cool down with the furnace.

In the electric oven, a casting weighing up to about 8 tons can be heat treated as nearly exact as small pieces in a laboratory furnace. Working with the gas-fired furnace this exactness is not as readily obtained, necessitat-

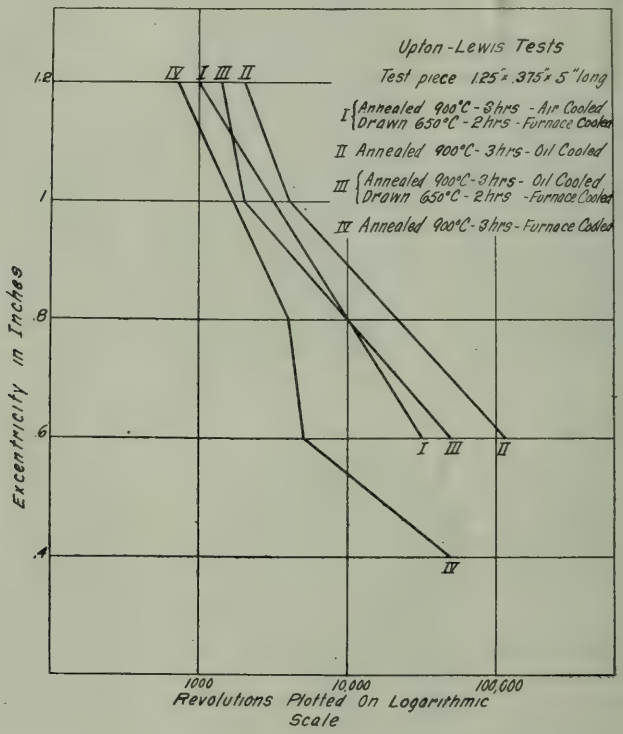

Upton-Lewis Tests
Test piece 1.25" x .375" x 5" long
I {Annealed 900°C - 8 hrs - Air Cooled / Drawn 650°C - 2 hrs - Furnace Cooled
II Annealed 900°C - 3 hrs - Oil Cooled
III {Annealed 900°C - 3 hrs - Oil Cooled / Drawn 650°C - 2 hrs - Furnace Cooled
IV Annealed 900°C - 8 hrs - Furnace Cooled
Excentricity in Inches
1.2
1
.8
.6
.4
IV I III II
I III II
IV
1000
10,000
100,000
Revolutions Plotted On Logarithmic Scale

Fig. 13—Upton-Lewis Tests on Specimens Taken from Four Different Castings of About the Same Weight. Their Treatment is Indicated on Chart. The Results Shown Here are Representative of Regular Production Output

ing much more skill on the part of the operator and the results in most cases are not as good as those obtained in the electric furnace.

The described process is also very well suited for medium and hard castings when no drastic heat treatment is possible. During the cooling down a high tensile strength will be imparted to steels showing about .35 carbon and upward, and in regulating the following low temperature treatment wide variations in the strength and toughness of the material can be produced. Castings too low in carbon can likewise be brought up to the desired strength without risk of warping. The toughness even of big castings of mild steel subjected to the described treatment will show much higher figures compared with those obtained through slow cooling in the furnace from the annealing temperature. This point is not sufficiently recognized in the treatment of steel castings, as a much more drastic cooling is thought to be necessary.

The heat treating department will further be capable of a greater output

when operating with the electric furnaces, inasmuch as the castings will be finished in about 8 hours less time.

Years ago in standardizing the furnace handling of castings at Stavanger Electro-Staalverk, some endurance tests were made on steels corresponding to various heat treatments. Fig. 13 shows the result of a set of tests on steel for hydroelectric power machinery obtained in the Upton-Lewis machine. The test-bars were cut from castings of approximately the same weight (100 to 150 kilograms), which had undergone a heat treatment in the electric furnace as indicated on the chart, Fig. 13, the truckload in each case being 8 to 12 tons. The results therefore are thought to strictly correspond to the regular output, if treated as indicated. Fig. 13 demonstrates that at least for these small castings, oil and air-cooling with a following draw at 650 degrees Cent. gives nearly equal results, furnace-cooling gives decidedly lower values.

Summary

It is possible by proper heat treatment to bring the impact figure in steel castings nearly up to the toughness, which can be obtained in high nickel chromium steels for case hardening purposes. This refers to electric steel with about .20 carbon handled with great care during all stages of the process and subjected to a very mild heat treatment, or rather to be called repeated annealing, as no drastic cooling is used.

The author does not in any way claim originality in the advocated treatment, as many heat treaters have at times undoubtedly been forced to similar processes, but he does wish to show that specifications regarding impact toughness may be laid down and that they can be obtained by suitable heat treatments.

(*Continued from Page* 421)

SOME FUNDAMENTALS OF RESEARCH

course, to prevent overlapping of duties, with possibility of discord. The utmost of harmony and co-operation is essential in any organization. (The organization chart of the research laboratory of the General Motors Corporation, which details the problems confronting this organization, may be of interest and is included as a part of this paper.)

Research organizations must be schooled continually in simplicity of effort and measure their results by the yardstick of utility. The results of research work are ofttimes intangible; for, after all, the general product of research is *information*. That information must be founded on facts which, when worth while, can always be carried in small packages.

THE NEED FOR MORE PRACTICAL INFORMATION IN INDUSTRY

By Dr. J. S. Unger

Abstract

The paper makes a plea for more reliable data and information concerning many of the phases of endeavor in our industries. The author points out that there is a large amount of investigative work done which is of little value to anyone often including the investigator. Many people labor under the misapprehension that they are well informed on their subjects but in reality they are poorly informed.

Suggestions for possible researches and investigations are made by the author.

AT THE outset, the writer wishes to say that this paper is not a scientific one. In the steel business and such other industries directly connected with the steel business, frequent inquiries are made for information on certain subjects upon which an immediate reply is desired. To wait until an investigation can be made, may require days, months, or perhaps years and when completed, may then not be of value, as the question probably has been answered more or less completely by an actual experiment or trial, or from another source.

Need for Reliable Data

The motive which prompted this paper was the necessity of having complete data on hand or of constantly investigating subjects of practical value to the business and technical world. Many investigators are at work on problems that for the present are only of abstract value. The usefulness of the results will depend alone on their practical applications. The investigator does not have a fixed, definite practical aim or goal to which he may apply his results. The consequences are that the data obtained are not applied to a definite purpose and are eventually lost. Later, another may go through the same process and meet with the same results. History repeats itself. Until the information is actually applied to a given purpose, it is that much timber thrown to one side to decay.

The point which is emphasized is the lack of dependable information. Many people believe they have a thorough knowledge of a subject, but instead they simply have a smattering. Their knowledge or ignorance consists of opinions, something others have said, something they have read, or conclusions reached by them without any attempt on their part to prove or disprove their opinions.

In order to emphasize this, I will tell you of a number of incidents, being the experience of myself or others and you may be assured that they are not funny stories, but facts.

A gentleman, who had no claim on the chemist, and trying to get something for nothing, asked for the composition of rust on Bessemer and open hearth steels. He later explained he proposed to use it in some of his personal advertising matter. The chemist furnished the information gratis

A paper presented before the Pittsburgh Chapter. The author, Dr. J. S. Unger, is manager of the Central Research Bureau of the Carnegie Steel Co.

from results in his files. The analysis had not included combined water, oxygen or carbon dioxide. Imagine the chemist's feelings, when he was told publicly that the analysis was wrong, intimating the chemist was not dependable. A little information on the subject was needed in this case.

A young metallurgist was drawing back a furnace charge of steel pieces weighing about 1000 pounds each, at a temperature between 550 and 600 degrees Cent. as shown by a pyrometer which was placed at the middle of furnace lying on one of the pieces. An inspection by the eye while the gas was shut off the furnace for about one minute showed a temperature of somewhere between 750 and 800 degrees Cent. On checking the temperature with two extra pyrometers, temperatures of 785 degrees Cent. were found. The entire charge was spoiled having to be retreated from the very beginning. An absence of practical information is lacking in this case.

A works metallurgist who had just finished a long dissertation on the hardening of steel, explaining all about austenite, martensite and troostite, was asked what kind of case hardening compound he used, and at what temperatures he carburized and quenched his material. He could not give an answer, hiding his ignorance by sending to the shop to get information from one of the workmen.

Many Salesmen Little Informed on Their Products

Many salesmen fail because of a lack of knowledge of the real advantages or disadvantages of their goods, and a positive ignorance of the properties the article must possess to best fit it for what it must do in service.

An agent selling fluorspar was told by the customer, it must contain not less than 78 per cent calcium fluoride, not more than 5 per cent silica, nor more than 10 per cent calcium carbonate. He was very indignant claiming such requirements were impossible as it did not add 100, nor was any allowance made for the remaining compounds.

Brick representatives sometimes carry samples which they present, together with an analysis and the melting point of the brick. The samples are carefully selected to insure good workmanship, and freedom from surface defects. They claim almost everything for the quality. A carload shipment will show cracked, warped, broken brick, and some which differ in thickness by ½ inch. The chemical analysis is of little value, as the properties are profoundly affected by the manner of making. The melting point is of very little value, as the bricks could not be used at or near the melting point. The softening point or the ability to sustain a working load at working temperatures, (not in the cold condition), has not appealed to them. An absence of necessary knowledge is apparent.

A complaint was entered with a maker of steel ladle refractories. The stoppers he furnished were not round and would not fit the nozzle, making a liquid tight seat. This is essential to avoid a spattering of the steel over the moulds and cars, giving constant trouble. After he had presented a number of his regular make, which he considered perfect stoppers and finding they were unfit to use, being about as round as a horse's head, he prepared a new scale of prices, covering, No. 1 Regular; No. 2 Round; No. 3 Round and Polished. He could not see why his regular product was not good enough, although it was not tight for liquid steel, nor could it be used without entailing expense to the user. He had not studied working conditions.

How many agents for bearing metals know the physical properties of the white soft metals or the brasses or bronzes they sell. In most cases the

composition is a secret. When asked about the hardness, the compression, the strength, the ductility and the shrinkage, the best temperature for melting and pouring, and information on the frictionless quality, they can tell you little or nothing, yet these properties are the important things the user should have. Some manufacturers make regular tests, particularly in the brasses and bronzes, others do not. Very little testing is done on the soft metals, although two soft metals of approximately the same cost may show a difference in service of as much as 20 times.

A man selling a belt dressing made by a secret formula insisted it "gave life to the leather," and increased its strength. A short piece of leather belting was cut into two adjacent strips. He was given one piece to dress with his preparation. He returned the next day claiming the leather was more pliable and improved in strength at least 3 times. Much to his surprise he was shown that by soaking the leather in water a few minutes, the pliability was increased. The strips were tested to destruction. The dressed piece showed 80 per cent of the strength of the undressed. A clear case of lack of information.

A strip of leather was cut into 4 short pieces. The alternate pieces given to another representative to dress. The dressing smelled of tar and rosin but he insisted it contained nothing but animal greases. All samples were tested to destruction. The dressed pieces averaged 78 per cent of the undressed, and even then he wanted to argue the matter.

A secret dressing was applied to a strip of leather. Thirty minutes after application, it increased the adhesion or gripping quality on the pulley to four times that of the undressed strip. On being laid away for 3 days, it had fallen to 2½ times, after one week to 1½ times. The rapid decrease in adhesion was not hastened by any service.

A strip of leather laid in kerosene for two hours showed a decrease in strength of 40 per cent when tested the following day.

Many persons, some of whom, claim to know much about leather, will tell you that the thick part of a leather butt is much stronger than the thin. When asked to show their figures, they do not have any, nor can they understand why thin and thick strips from the same hide will prove the question in any way desired.

Some round steel rods in service were subjected to severe bending stresses, causing buckling or slight permanent bending of the rods, resulting in rapid failure from fatigue. The user claimed the rods were of poor quality, saying the steel of several years ago was of much better quality. He believed the composition and micro-structure was at fault and he was helpless. In going over the service records, it was found the service at the present time was in some cases three to four times as severe as it was some years ago. By devising a bending test on full-sized rods, making it very severe, then trying out various steels from the soft to the hard grades, it was soon found that a special, medium carbon steel was the best in test and in service. The customer had done nothing to investigate the service, nor did he think service was his problem. He took the position that he prepared the finished article, and any failures were due to the quality of the steel. He was told the service was becoming more severe and that he must increase the size of the rods, otherwise, breakages would be more frequent than in the past. He objected to this, claiming it would cost more. Here is a case in which real practical information was not desired.

A customer for plate steel presented specifications covering the regular maximum and minimum tensile properties and bend tests. In addition he

stated he wanted higher carbon, as he claimed he wanted a stronger steel. He specified a carbon content fully .15 points higher than could possibly be used to meet his specifications. He resented being told it was impossible to make such material of common steel, insisting upon his requirements, believing perhaps the carbon was applied by the steel maker similar to a coat of paint. Did the customer have even a practical knowledge of steel?

A customer using strip steel 5 x ⅛ inches insisted much better results were obtained by using soft Bessemer steel than similar basic open hearth steel as the latter would not produce straight work. A shipment of open hearth steel was made and carefully observed in service. No difference could be found. It was discovered that the first lot of open hearth steel was not straight, having been kinked in service, consequently, the work done by the steel was not of good quality. This defect was immediately assigned to the kind of steel used.

A user of acid open hearth steel said basic open hearth steel could not be used in the making of a small, untempered, common spring. Basic steel of the same physical properties was furnished for a trial. After fabricating the new steel and testing it by a crude shop method, he adopted the basic steel. At this time he will not accept acid steel.

A metallurgist complained about some plate steel, stating it contained too much ferrite. The other observers who witnessed the work the steel was doing were satisfied. The steel was returned. Another plate from the identical heat was furnished and was pronounced very satisfactory.

A construction firm was much impressed by the claims made by a maker of special high-elastic, high-tensile steel. It being 50 per cent higher than their regular steel. They were interested, purchasing some of this steel, but found they could not shear, punch or bend it cold without cracking or breaking it. It had to be worked at a red heat. They did not possess the equipment to work it hot, nor could they add the extra cost of the steel and the additional cost of working to their product. If the steelmaker had a practical knowledge of what was required of this steel he would not have recommended it for their purpose.

A complaint was received from a customer that rails furnished him were defective. He had the steel examined microscopically by a well-known firm of testing engineers, who submitted a report with micrographs, stating that they showed the presence of an excess of ferrite for this grade of steel. A letter was received from this customer, inclosing a copy of report with this notation: "You will note there is an excess of ferrite, which I believe is due to ferrite in the ore used in making this steel."

Steel rails are purchased by specifications, covering composition, drop tests, breaking tests and bending tests. A rail may meet such tests and give poor service, while another may fail in tests and give good service. Have the tests been correlated with service? Do the present tests really procure good rails? Have any comparisons in track been made by the railroads under exactly the same conditions to determine what qualities a rail should possess?

Hardness in metals may mean anything. We have rolling hardness, abrasion or scratching hardness, machining hardness, impact hardness, and resistance to deformation. A manganese steel rail may show a lower Brinell hardness than an ordinary rail, but may show a rolling hardness of 4 times that of the ordinary rail. Two steels of the same Brinell hardness may show twice as much resistance to machining when compared. With different metals, say

cast iron, bronze, hardened copper, and soft steel, very much greater differences in machining are found than in the Brinell hardness. Abrasion of steel by grit, sand or by grinding does not depend on the Brinell hardness. A soft steel compared with a medium hard steel, showed the following comparison:

Steel	Ultimate Strength	Brinell Hardness	Resistance to grinding by Carborundum Powder
Medium Hard	100 per cent	100 per cent	100 per cent
Soft	58 per cent	50 per cent	77 per cent

We need to know more about hardness, as what may be hard in one case may be relatively soft in another.

The resistance to corrosion of steel is sometimes determined by its resistance to solution in partly diluted acids or in a solution of brine. Exposure to the condition of service is not universally practiced, as it sometimes requires years for completion. The first tests are used as an index of quality even though they bear no relation to the resistance in service. Why should any confidence be placed in such tests?

It is sometimes assumed a good paint for wood is a good paint for metallic surface. Metallic surfaces may be hot as a boiler, a furnace or a hot blast stove. At times the hot surface may be drenched by a rain storm. Perhaps the paint may adhere but not protect the steel, at other times the paint will protect the steel but will not adhere, owing to the conditions of service. Should paints be selected for what they must do?

Many metals or alloys are added to steel to take out the gases, particularly oxygen. Anything that has an affinity for oxygen may be advocated. Some of those whose affinity is greatest at a low heat, function improperly at a high heat. Others are the exact opposite. Experiments have shown that outside of an actual trial, it is useless to say what a particular deoxydizer added to steel will do. Claims are advanced for the gaseous purification of steel by almost every new alloy produced.

Whether you are a producer, a consumer or salesman, more than beliefs or opinions are necessary. Practical information on your particular subject is essential.

Suggestions on Practical Problems for Investigation

There are many practical problems that require further investigation, and among the many in the steel industry, the following are a few examples:

1. What effect has superheated steam up to say 318 degrees Cent., 599 degrees Fahr., on the physical properties of the medium and high carbon steels? What effect is produced if such steels be cooled in hot water resulting from the condensed steam?

2. What force per square inch is required to compress or upset both alloy and plain carbon steels when they have been heated to working temperatures, or from 1000 to 1200 degrees Cent. such as would be used in rolling, forging or forging in a die? These steels to have the same physical properties in the normalized condition when cold. The same data for steels of unlike physical properties when cold?

3. What is the strength of various steels heated continuously from 500 to 900 degrees Cent. for many hours in a vertical furnace used to

heat guns or shafting for quenching or annealing?

4. Which is better, a casting or a forging, used under the above conditions for a suspending device?

5. What proportionate reduction of area from an ingot to a rolled or forged piece is of value? At what point might the reduction cease as being of no further benefit other than that it would give a lower finishing temperature, resulting in better grain refinement?

6. Do the projections on twisted or otherwise deformed bars for concrete reinforcement add anything to the strength of the concrete structure as a working unit?

7. Is the X-ray of value in showing an interior defect in steel if the sides of the cavity lie close together?

8. Through what thickness of steel is it commercially practicable to secure a radiograph clear and distinct enough to be of value?

9. Can interior defects in steel, the sides of which lie close together be shown by magnetic examination?

10. Which has the better properties,—a sound properly heat treated steel casting or a forged or rolled piece of the same steel and same heat treatment?

11. Does the addition of a few hundredths of a percent of phosphorus to basic open hearth steel improve the welding properties?

More Practical Information Needed

In closing I want to leave a few thoughts with you. Our journals and magazines contain many articles describing work done in a very small way. A few small specimens or examples are used from which broad general conclusions are drawn, not adapted to service nor practicable of execution.

To secure real practical information the tests should be made on as near the full-sized material as possible and under conditions closely approaching service. Such tests must be more severe than actual service, otherwise, the test is unduly prolonged. Sometimes this can not be avoided. Service is not standard, as many variables exist which may lead to the wrong conclusions. Any kind of service is not a true criterion of service. Service tests must be carefully standardized in order to repeat them if necessary. It is always wise to use a unit for comparison or a measuring stick of a known material in conjunction with the unknown in service, to be certain of results. If tests be made, they must be of such character to be correlated with service and show qualities of actual value.

Much time is spent in trying to find a reason for certain phenomenon, and many theories have to be advanced to explain it. The isolation of a particular disease germ is of great value, but the greater benefit is obtained by finding out how to combat or destroy it. We do not know just what electricity is, but we do know how to use it to benefit mankind. Instead of spending so much time trying to find the cause, we should take the effect as it exists, and try to improve the condition, not by theorizing, but by actual trial or tests.

My aim in this paper, and I hope I have shown it, is the need for more practical information in industry.

A METALLOGRAPHIC STUDY OF HOLLOW ROCK DRILL STEEL, AS INFLUENCED BY THE METHOD OF MANUFACTURE

By N. B. Hoffman

BY THE term *hollow rock drill steel,* the author refers to bars of tool steel either round, hexagon, octagon, quarter octagon or other suitable sections containing a round hole running the longitudinal axis of the bar. The hole in the bar has several functions, most important of which is the passing of water through the bar during drilling to the cutting face of the tool, thereby eliminating dust and at the same time washing out the pulverized rock as fast as produced, thus giving the tool a clear working area at all times. Another great virtue is its protection to the health of the driller, due to the elimination of dust.

Hollow rock drill steel without doubt had its inception in England, and one of the earliest patents recorded for the manufacture of hollow materials, rods or tubes, was granted to James Newman, of Birmingham, England, on Nov. 28, 1854. This product, however, was not used for rock drill steel, but the process finally led up to its production. Newman's patent covered the invention of lap welding skelp, and filling the resultant tube with sand, then drawing it out through rolls, after which both ends of the rod or tube were cut off and the sand drilled out. The method employed in England and the United States today, covers the same general idea, that of filling with a refractory material, and removing same after rolling.

Method of Manufacture

The following is a brief description of the method used at the present time. A hole is drilled through the center of a bar or billet along its longitudinal axis, and of sufficient size to produce a hole of a given diameter in the finished bar after rolling. The hole in the billet or bar is next filled with a suitable refractory material and both ends plugged. This billet or bar is then hot rolled to the size desired, and when cold, both ends are cropped and the filling material removed, employing one of two methods, either by air or water pressure. Several other methods of manufacture are used in the United States, but the general idea of filling the hollow billet or ingot with a refractory material, and after hot rolling removing the filling material, has proved to be the most satisfactory and has been generally adopted.

In Sweden, a prominent producing center of hollow rock drill steel, other methods have been adopted for keeping the hole open in the stock during the rolling process. In some instances the billet is pierced and rolled down with mandrels inserted through the hole, which are taken out and exchanged for ones smaller in size each time the piece is passed through the roll. Another method commonly used, is to first pierce the billet, and then keep the hole open during rolling by forcing a current of air through it at high pressure and thus cool it while the remainder of the piece is still hot. The compression and contraction in size, therefore does not close up the hole entirely. While the finished

---

A paper presented before the Detroit Convention, October 2-7. The author, Dr. N. B. Hoffman, is metallurgist with the Colonial Steel Co., Pittsburgh, Pa.

product made by the various processes are similar in character, yet each type differs slightly from the other in some degree.

Until the last two years, practically all rock drill steel used was made of carbon steel, the alloys being neglected. But the demand for production and the gradual increase in size of the pneumatic drilling machines, placed an unusually heavy burden upon the rock drill, and many mining engineers began asking for a better quality of steel to enable them to increase their efficiency and production, much of their trouble being due to breakage and low cutting efficiency of the bit. What they needed was a steel which would withstand impact and at the same time retain a sharp cutting edge. That is a steel with a tough stiff body with high fatigue values, and a point which when forged and hardened, would be both hard and tough, and one that would hold its gage under all conditions.

In developing a steel with all the foregoing qualities, several other factors must be taken into consideration. First, it must be of a composition that any blacksmith can easily forge and heat treat. Secondly, its price range must be such that it will not be prohibitive to the smallest consumer. In developing such a product, we naturally turn to the alloy field. Chrome, chrome vanadium, chrome nickel and various other alloy combinations have been tried, and I believe without result, due in great part to the complexity of heat treatment. The composition found to give excellent results in actual practice thus far, is a vanadium steel with a composition as follows:

Carbon	.75-.85
Manganese	.25-.35
Phosphorus under	.020
Sulphur under	.025
Silicon	.12-.16
Vanadium	.20

A large number of tools of like character, and the nature of whose work required similar properties, have been used in the industries for years and have to a very great extent displaced the carbon steels. A steel of this type has excellent fatigue values as well as stength. A 1¼-inch cube quenched in water at 1500 degrees Fahr. and drawn in oil at 415 degrees Fahr. will withstand a compression load of 250 tons, and in crushing down seems to tear apart, while the carbon steel shatters. It also has a scleroscope hardness as high as the carbon steels.

Francis B. Foley, metallurgist of the United States Bureau of Mines, in a paper presented before the American Institute of Mining and Metallurgical Engineers, Feb. 19, 1922, quoted some very interesting data from the *Canadian Mining Journal* of Jan. 15, 1917, which shows that most of the breaks in rock drill occur during the early life of the steel, and that as a given batch of steel is used, its percentage of breakage decreases, and that this fact is at variance with the much-talked of theory concerning failure from crystallization and fatigue. It seems to point to the fact that the greater part of drill steel failure from breakage, is traceable to faulty manufacture resulting from defects in the bore of the hollow steel, such as slag, oxides, etc., and as this defective material meets with early failure, it is weeded out. In addition, some breakage may be caused by a lack of proper condition with

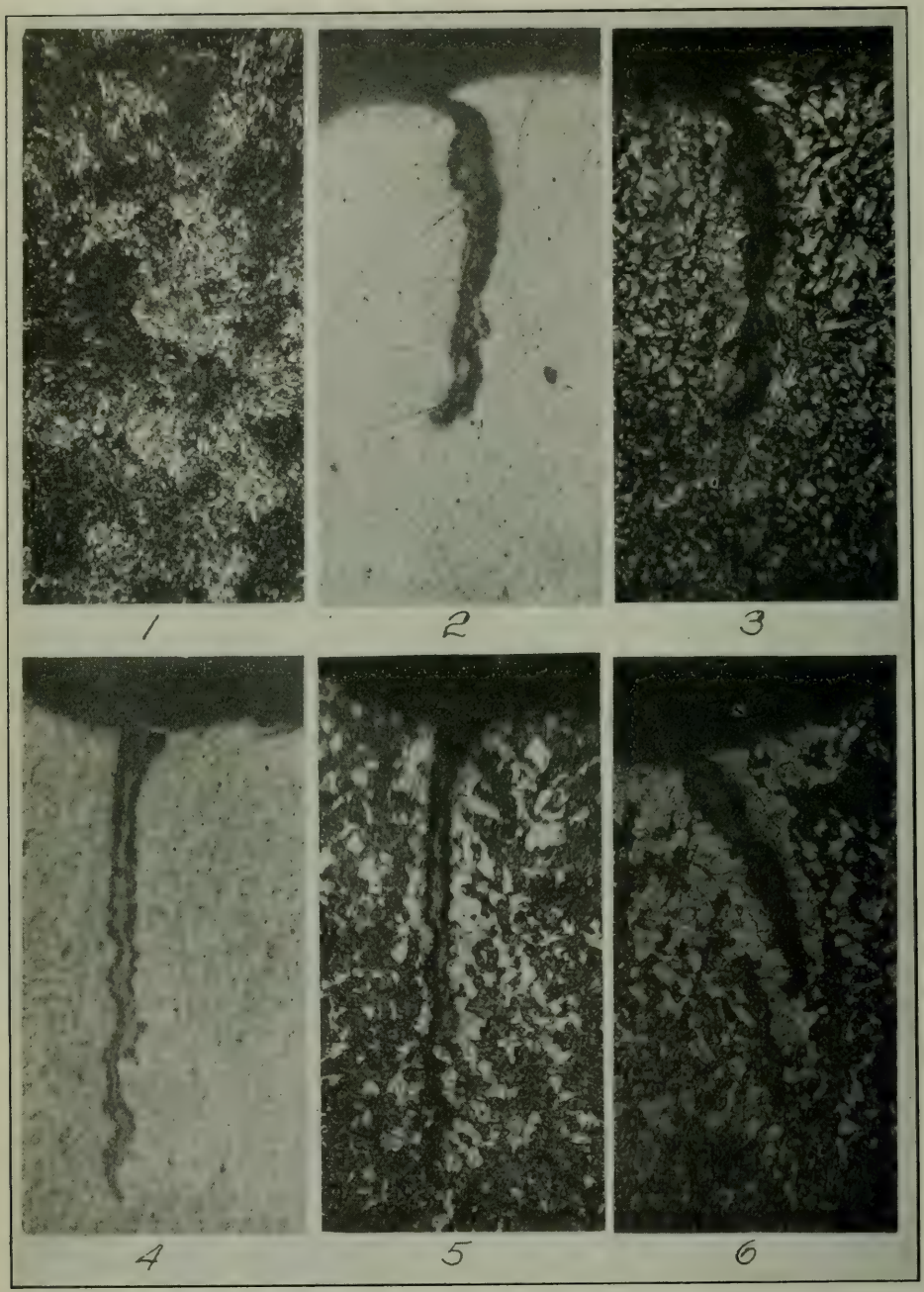


Fig. 1—Normal annealed structure of bar. Fig. 2—Showing crack on a polished and unetched annealed section. Fig. 3—Same as Fig. 2 after hardening and etching. Fig. 4—Polished and unetched hardened section showing crack. Fig. 5—Same as Fig. 4 after etching. Fig. 6—Another hardened and etched area showing crack. Note the completely decarburized area surrounding the hole as shown at left of photomicrograph. All magnifications × 100.

respect to heat treatment of the steel as furnished by the manufacturer. These points would seem to be well taken and worthy of serious consideration.

Bits Fail Due to Fatigue

The question of fatigue to withstand vibratory shocks and stresses, would seem to be absolutely vital to the production of a successful rock drill steel. But several interpretations are placed on the word *fatigue* and I will quote you from the analysis given the term by Prof. H. F. Moore, of the University of Illinois, who has done much work on the fatigue of metals. He says, "the view is summed up in the word *crystallization*." The idea was that under repeated stress the material changed its crystalline structure, and he states "that he does not know of any evidence in favor of the theory that metals materially changed their crystalline structure under repeated stress. The crystals are broken under repeated stress." The second theory, advanced by Bauschinger, the German scientist, is that "under repeated stress some inherent property of the material changes its elastic limit, it is an inherent property of the material, possibly some property of the amorphous cement between the crystal." The third view is that all fatigue of metals is the result of the spread of damage from little localized overstresses.

Prof. Moore, says he does not feel justified in stating his positive belief in the third view as against the second, but has yet to find a case of fatigue of steel or other metal, either in the laboratory or in service that could not be explained by the gradual spread of damage from some nuclei. While feeling satisfied that breakage is caused by the gradual spread of damage from nuclei or weak spots such as radial cracks, slag or oxide pockets, yet a steel with high fatigue values would fail far less early than one with low values.

Test Procedure

Tests were run using a plain carbon steel and a vanadium steel to determine their shock resisting or fatigue qualities, using 4-foot test bars as a standard. The bit ends of the test bars were faced off flat similar to the chuck ends. A 248 Ingersoll-Rand drill, mounted on a column, was used for all tests. The tests consisted in using the test bars like a drill steel, allowing the bit end to strike against the face of a sixteen pound sledge, wedged in a 4-inch diameter hole in the solid rock. An adjustable arm with a 1 7/16 inch diameter hole in it was supported from another column, so that the test bar could be placed through the hole and the arm adjusted so that the hole would line up with the chuck of the drill. The test bar being placed through the hole in the adjustable arm could not get out of line. Care was taken also, to see that the flat bit end of the test bar struck the face of the hammer squarely. The adjustable arm supported the test bars 12 to 14 inches from the bit end. Care was taken to see that the sledge did not show movement during tests. The bars were tested by operating the drill until breakage occurred, noting the time in minutes and seconds.

The size of the steel used was 1¼ inch hollow round, and all bars were 4 feet long. Five test bars of carbon steel and three of vanadium

steel were used. All blacksmithing and heat treating was performed by the same man and conditions were as nearly identical as possible.

The result of the fatigue tests showed the vanadium steel to have a life over three times as long as the carbon steel.

Numerous tests have been run in actual drilling operations which have shown the vanadium steel to have fatigue values at least 50 per cent greater than carbon steels or at least the breakage is reduced 50 per cent.

To get a comparison in actual working conditions, a carefully conducted test was run by a large gold mining company using 10 bars of 1-inch hollow octagon carbon steel, and 10 bars of 1-inch hollow octagon vanadium steel. The two steels were manufactured exactly alike in every detail and the only difference was that 10 bars contained approximately 0.20 per cent vanadium. The samples were run side by side for four months in stopes of hard rock, and a breakage record of the two steels was kept with the following results:

	Percentage of Breakage in four months	
	3-ft. Drills	4-ft. Drills
Carbon Steel Hollow Drill	5.69	4.48
Vanadium Steel Hollow Drill	2.46	2.19

In practically every case where comparative tests of vanadium and carbon drills were run, the results showed the vanadium steel to have at least 50 per cent less breakage and that it held its gage 30 per cent to 50 per cent longer.

The hollow rock drill manufactured by piercing and chilling with air or that manufactured by piercing and rolling down on mandrels, abound in minute cracks or folds radiating from the hole in the bar; which areas would seem to be weaker than the areas surrounding them. Another feature of the pierced and rolled or drawn bar, is that the area surrounding the hole is decarburized to various depths. This is true of all other pierced stock that I have ever seen no matter for what purpose used. But in practically every instance to my knowledge where the pierced stock before using is hardened and drawn and used as such in other classes of work, the decarburized area is removed in machining operations incidental to the forming of the tool.

Types of Steel Tested

The first two samples examined were of the type in which the holes were kept open during rolling either by means of mandrels or compressed air.

The sections examined in the first sample, and as represented in photomicrographs, Figs. 1 to 6 inclusive, were cut from a 1¼-inch round, and had the following chemical composition.

Carbon	.82 per cent
Manganese	.21 per cent
Phosphorus	.023 per cent
Sulphur	.017 per cent
Silicon	.11 per cent

This bar had numerous radial cracks or folds radiating from the

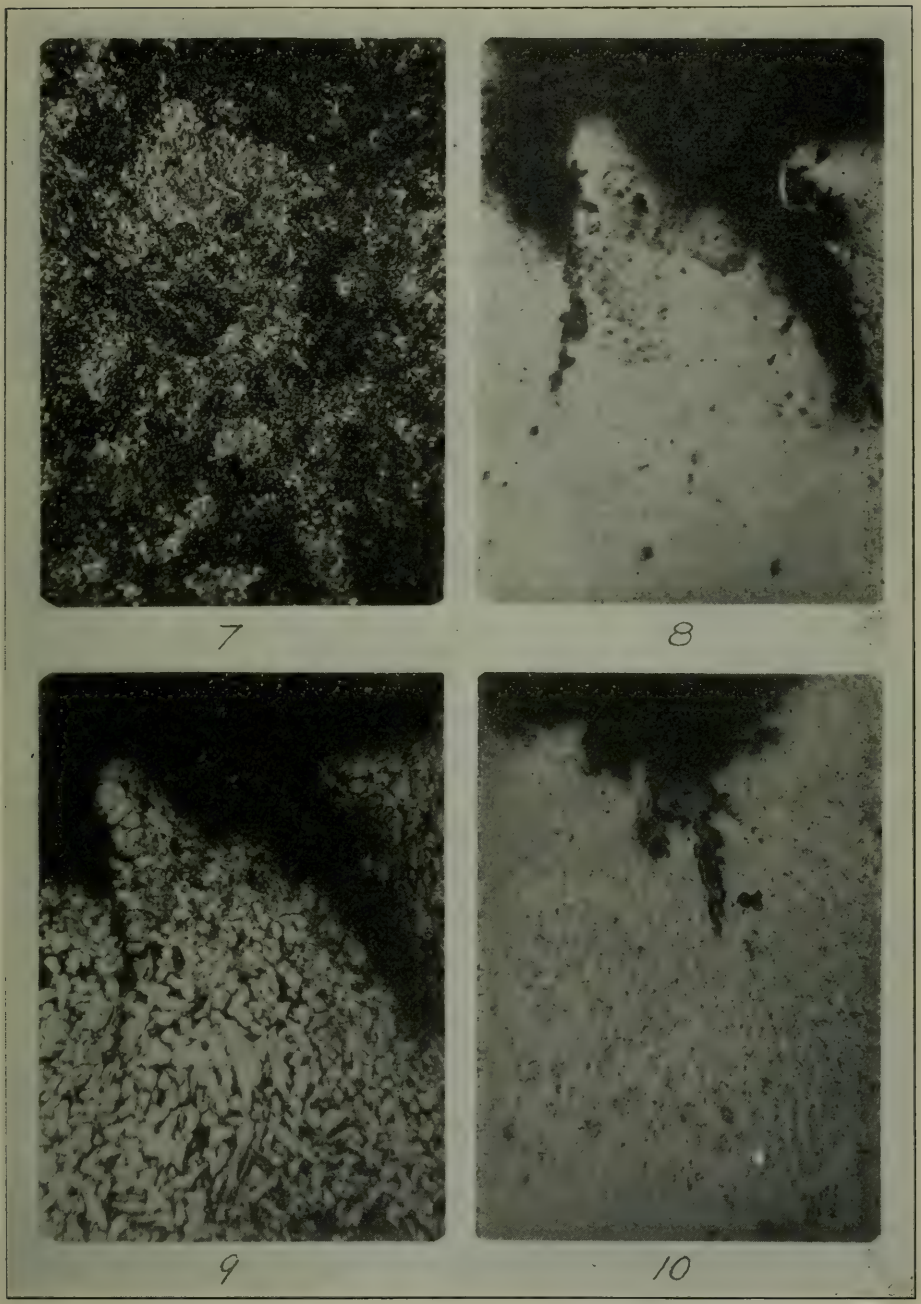


Fig. 7—Normal structure of annealed bar. Fig. 8—Photomicrograph showing two folds or cracks running in from hole. Specimen annealed and polished but unetched. Fig. 9—Same as Fig. 8 after etching. Fig. 10—Hardened and polished area showing crack extending from the hole into the bar. All magnifications × 100.

hole, and while the metal in the area surrounding the hole is decarburized to a more or less uniform depth, yet the area surrounding the cracks or folds is decarburized through their entire length, which in some instances was 3/16 inches deep. These areas would absolutely represent weak points in the bar and early failures would undoubtedly occur through those areas.

All photomicrographs shown are 100 diameter magnifications, and all etching was done with nital.

Photomicrograph Fig. 1 is representative of the normal annealed structure of the bar, while photomicrograph Fig. 2 shows a crack or fold ⅛ inch deep on a polished and unetched annealed section, extending from the hole in the bar as shown at the left of the photograph.

Photomicrograph Fig. 3 represents the section shown in photomicrograph Fig. 2, after hardening, as etched to show the grain structure. The heavy white areas of ferrite low in carbon, extend beyond the fold and the carbon content of the whole area would possibly not be more than 0.20 per cent.

Photomicrograph Fig. 4 represents a polished and unetched hardened section containing a crack or fold 3/16 inches deep, extending from the hole in the bar as shown at the left of the photograph. The mottled area extending from the defect, shows the extent of decarburization, that immediately adjacent to the crack is totally decarburized, from which point decarburization graduates into the bar.

Photomicrograph Fig. 5 represents the area shown in Fig. 4 after being etched, and portrays the lines of complete decarburization as seen to better advantage in the heavy white areas, as well as the gradual decarburization into the body of the bar.

Photomicrograph Fig. 6 represents another hardened and etched area of a fold or crack, showing the completely decarburized area surrounding the hole as shown at the top of the photograph, and that adjacent to the defect in the bar, as seen in the heavy white areas, as well as the gradual decarburization into the body of the bar.

A second sample of the preceding type examined was also cut from an 1¼ inch round and had the following chemical analysis.

Carbon	.90	per cent
Manganese	.23	per cent
Phosphorus	.020	per cent
Sulphur	.017	per cent
Silicon	.14	per cent

This bar also had numerous folds or cracks running through it radiating from the hole, but in this specimen we do not find the defects extending so deep in the bar as in No. 1, while the decarburization in many areas was deeper.

Photomicrograph Fig. 7, is representative of the normal structure of the annealed bar.

Photomicrograph Fig. 8, on the top of the photograph representing the hole, shows two folds or cracks on a polished and unetched annealed specimen extending from the hole into the bar.

Fig. 9, represents the section shown in photomicrograph Fig. 8,

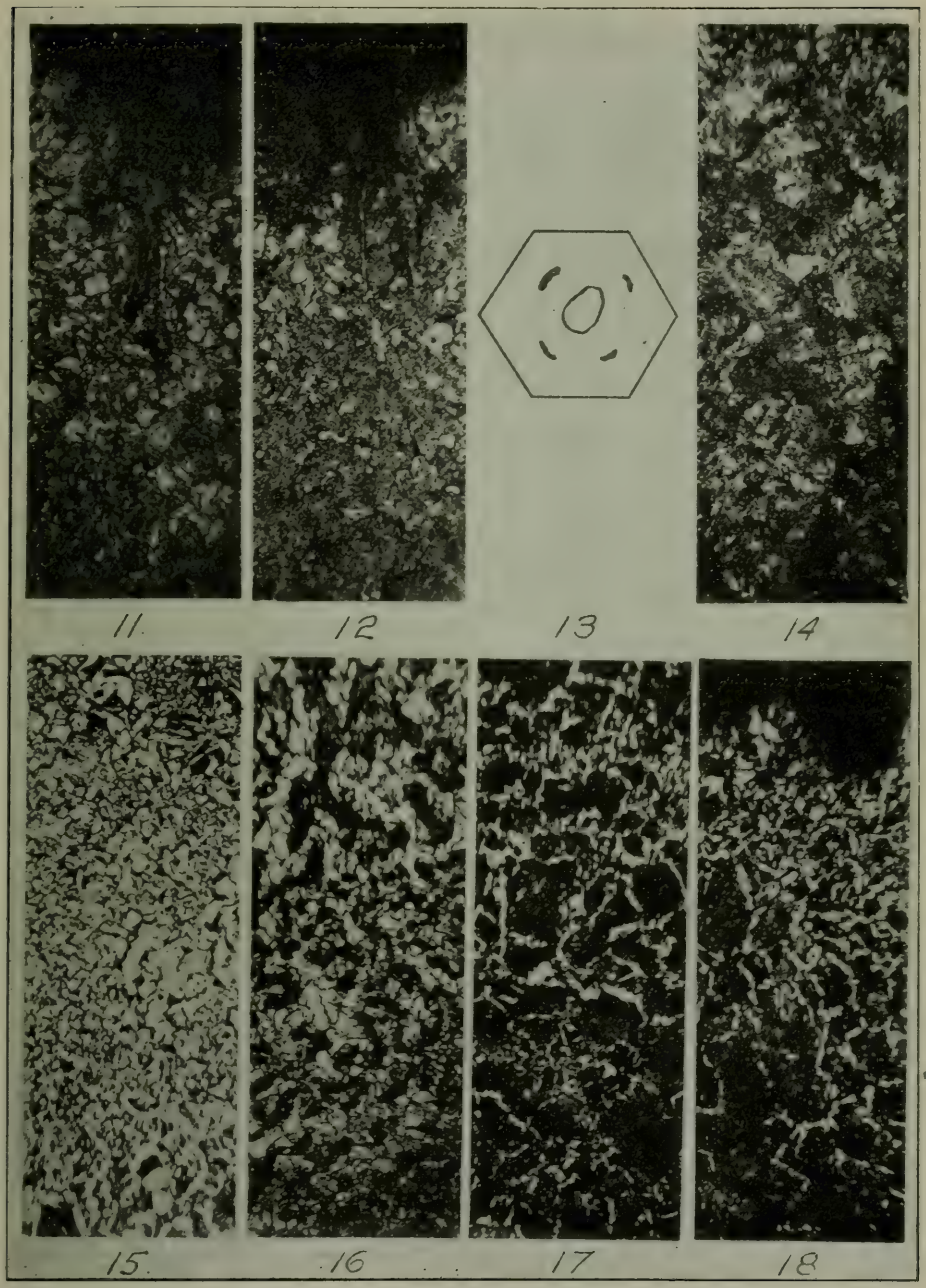


Fig. 11—Same as Fig. 10 etched. Fig. 12—Shows hardened section adjacent to hole. Fig. 13—Sketch showing location of soft spots caused by the method of casting the ingot from which the bar was made. Fig. 14—Normal structure of annealed bar. Fig. 15, 16 and 17—Specimens polished and etched to show grain structure in three of the soft spots. Fig. 18—Annealed area adjacent to hole, showing rough edge but no cracks. All magnifications × 100.

as etched to bring out the grain structure. The heavy white areas of ferrite low in carbon extend ¼ inch into the body of the bar. The surface of the hole is shown at the left of the photomicrograph.

Photomicrograph Fig. 10, is a hardened and polished area showing a crack or fold extending from the hole into the bar as is shown at the left with the mottled-like areas of ferrite low in carbon adjacent and extending beyond its tip in the body of the bar.

Photomicrograph Fig. 11, represents the area adjacent to the hole as shown in Fig. 10, when etched to bring out the grain structure. The heavy white areas of ferrite are almost completely decarburized.

Photomicrograph Fig. 12, is a view of another hardened section adjacent to the hole in the bar, as shown at the top and shows a slight crack or fold with the ever present area of ferrite low in carbon.

The next sample examined was a ⅞-inch hexagon bar with the following chemical composition.

Carbon	.70	per cent
Manganese	.21	per cent
Phosphorus	.007	per cent
Sulphur	.018	per cent
Silicon	.14	per cent

This specimen was manufactured from a hollow ingot cast as such and not drilled, but the hole in the ingot was kept open during rolling by filling with a refractory material. This bar showed four soft spots each of which formed a corner of a square, approximately half way between the hole and the edge of the hexagon as shown in sketch Fig. 13. This condition was caused by the method of casting the ingot from which the bar was made and not by any subsequent rolling operation. Photomicrograph Fig. 14, represents the normal structure of the annealed bar.

In photomicrographs Figs. 15, 16, and 17, the samples are polished and etched to show the grain structure in three of the soft spots. The heavy white area of ferrite in Fig. 15, shows it to be almost completely decarburized. Photomicrograph Fig. 16, shows one of the spots after a section of the bar had been hardened showing the soft grains of ferrite which will not harden. Photomicrograph Fig. 17 shows the area in that particular spot to be decarburized, although not as badly as in either Fig. 15 or 16. The carbon content was so low in the four spots that those areas could not be hardened. Photomicrograph Fig. 18, is representative of the annealed area adjacent to the hole in the bar, as shown at the top, and is very low in carbon. The edge is rough, but we have no cracks or folds.

We will next consider two samples of hollow drill manufactured by drilling the bar or billet and keeping the hole open during rolling with aid of a refractory material, which is the method most generally adopted in the United States.

The sections used in the first sample were cut from an annealed 1⅛ inch round bar, and had the following chemical composition.

Carbon	.83	per cent
Manganese	.31	per cent
Phosphorus	.009	per cent
Sulphur	.022	per cent
Silicon	.14	per cent

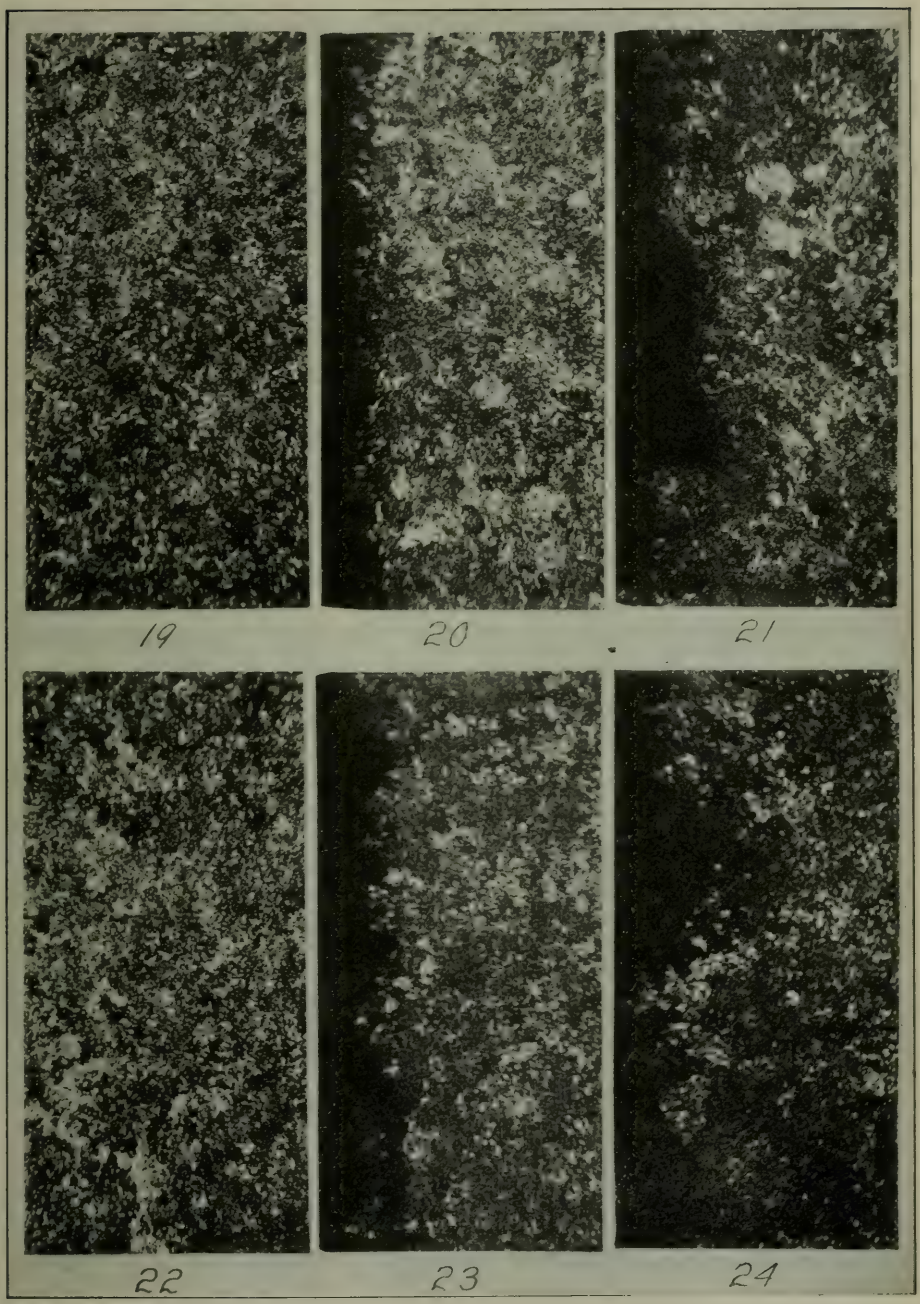


Fig. 19—Specimen showing a normal pearlitic condition. Figs. 20 and 21 are typical of the area surrounding the hole and shows no decarburization or cracks. Fig. 22—Polished and etched specimen showing a normal pearlitic condition. Figs. 23 and 24 are typical of the area surrounding the hole, showing no decarburization cracks or folds.

Photomicrographs Figs. 19, 20 and 21, are representative of the bar, and show the grain structure to be very uniform throughout, with no decarburization and no cracks, folds or weak spots radiating from the hole.

Photomicrograph Fig. 19, is representative of the polished and etched structure of the bar, and shows a normal pearlitic condition. Photomicrographs Figs. 20 and 21, are typical of the area surrounding the hole as shown at the left, and shows no decarburization, cracks or folds. Micrograph Fig. 21, shows the metal wall to be more uneven than in Fig. 20, but neither of them show anything that could be termed points of weakness in the metal wall.

The second sample considered is a vanadium steel of annealed 1¼ inch quarter octagon, and has the following chemical analysis.

Carbon	.85	per cent
Manganese	.28	per cent
Phosphorus	.007	per cent
Sulphur	.023	per cent
Silicon	.16	per cent
Vanadium	.20	per cent

Photomicrograph Fig. 22, is representative of the polished and etched structure of the bar, and shows a normal pearlitic structure.

Photomicrographs Figs. 23 and 24, are typical of the area surrounding the hole as seen at the left, and show no decarburization, cracks, or folds. Photomicrograph Fig. 23, shows the metal wall to be more uneven than in Fig. 24, but neither of them show anything that could be termed points of weakness in the metal wall.

Conclusion

In conclusion I would say the vanadium drill has one other strong point in its favor, that of heat treatment. In forging and heat treating the bits, the tendency is to carry the heat so high as to be injurious to the carbon steels, they having a comparatively narrow safe heat treating range, while that of the alloy bit is much higher thereby making it more fool proof.

While there is no doubt that considerably more carbon rock drill steel is being used today than alloy steel, yet I am a firm believer that before long conditions will be reversed.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

NEW QUESTIONS

QUESTION 61. *What are the causes of scaling or spalling of the case of a carburized steel?*

QUESTION 62. *What is the difference between annealing and normalizing steel?*

QUESTION 63. *What causes the surface of a carburized steel to become pitted as a result of carburizing?*

QUESTION 64. *To what extent can the deep etching of specimens of steel be applied to routine examination of incoming material?*

QUESTION 65. *What is the relation between the elastic tensile strength and the elastic compressive strength in ductile steels?*

ANSWERS TO OLD QUESTIONS

QUESTION NO. 27. *What is the function of the high phosphorus and the high sulphur content in the so called automatic screw stock steel?*

QUESTION NO. 35. *What is the difference between red annealed and blue annealed sheet steel?*

ANSWER. By A. L. Meyer, metallurgical engineer with the Alan Wood Iron & Steel Co., Ivy Rock, Pa.

The term *red annealed* is a misnomer, due to the fact that sheet steel being of red color has been rolled at a temperature below the critical range, which results in a red or ferrous oxide scale formation. Being rolled at such a low heat the sheet has become hard, due to lack of temperature for annealing and proper rearrangement of grain structure. This condition generally exists previous to the *blue annealing*. This latter condition is brought about by passing the rolled sheet through a furnace whose temperature is

above the critical range and whose condition will permit annealing and produce a blue or magnetic scale.

ANSWER. By E. J. Lowry of the Hickman, Williams and Co., Philadelphia, Pa.

Sheets are hardly ever sold in the original rolled condition. As such, they are called *red hard sheets*. It is believed that this is what the question refers to as a *red annealed sheet* which has not been commercially heard of. Nearly all sheets are annealed to be sold as *black plate*. The anneal consists of piling on a bottom and covering with a steel cover to prevent oxidation. This is known as box annealing. They are then heated to 1400 to 1600 degrees Fahr. for 16 to 20 hours. By another method, the sheets are allowed to cool after rolling and then passed singly through an open furnace where they are heated to the proper annealing temperature. The properties of the two kinds of annealed sheets are quite similar, the main difference being in the color. The latter method of annealing gives what are termed *blue annealed sheets*.

ANSWER. By G. A. Reinhardt, metallurgist with the Youngstown Sheet & Tube Co., Youngstown, O.

Mr. Reinhardt says: "I must admit that during my experience with sheet steel, I have never encountered the term *red annealed* sheets. Our sheet mill superintendent informs me that this is not a commercial phrase as he has never heard of it before.

"Annealed sheets are frequently spoken of as box annealed; white annealed or deoxidized; blue annealed; furnace annealed or pack annealed."

QUESTION NO. 46. Is the practice of buying high-speed steel by brand names instead of physical, chemical and metallurgical specifications justifiable?

ANSWER. By E. J. Lowry of Hickman, Williams & Co., Philadelphia, Pa.

The subject of "brands" is an interesting one. It has been argued for years and there have been established many "pros and cons" in nearly every industry. To justify it in metallurgical operations, one has to seek the traditions of the industry. Still further, its life has been the outgrowth of processes defined to make a product superior to a competitor's, and yet brand conveys little or nothing to the consumer. It does not guarantee the "pre-natal" conditions of the material. It is the producer who gives this guarantee. The brand is actually produced under chemical and physical specifications.

To adopt such specifications as science has to offer today, in purchasing material, will not, however, serve to eliminate the trouble which exists from a poorly made product. Neither can "brand" specification guarantee a product, but specification buying tends to aid the purchaser in standardizing materials, and is a step forward in progress, and is to be heartily recommended when used in connection with recognized producers.

QUESTION NO. 47. What is meant by "secondary hardness" in the tempering of high-speed steel?

ANSWER. By E. J. Lowry of Hickman, Williams and Co., Philadelphia, Pa.

Edwards & Kikkawa state as follows:

"The first effect of tempering hardened high-speed steels is to make them softer, but when they are tempered at higher temperatures they again become harder, and after heating at or about 614 degrees Cent. (1137 degrees Fahr.) they are much harder than in the initial air quenched state. There can be no doubt that this *secondary* hardening is the cause of the improved cutting powers of a tool, which Mr. Taylor found brought about by a secondary low heating to about 620 degrees Fahr.

"In order to get the maximum secondary hardness, the tungsten must have been placed in good solution by the primary hardening operation. It is very important to remember that different analyses of high-speed steel require different temperature treatments to obtain similar results."

QUESTION NO. 48. What are dendrites and how may they be detected?

ANSWER. By E. J. Lowry of Hickman, Williams and Co., Philadelphia, Pa.

Dendrites are the "pine tree" crystals caused by the freezing of metals from their molten condition. The branches enclose much of the impure metal, preventing its diffusion centerward. They are greatly aggravated when the metal is poured in contact with a "chill." They are commonly found in ingots and chill cast iron work.

Surface dendrites may be found by machining at right angles to surface. The dendritic structure shows up smooth and close compared to the openness of other grain structures.

QUESTION NO. 49. Can dendrites be removed through a proper heat treatment?

ANSWER. By E. J. Lowry of Hickman, Williams & Co., Philadelphia, Pa.

Dendrites may, in proper, be broken up by a proper heat treatment. The original contours of the grain will, however, always prevail. Mechanical work and heat treatment are the only reliable methods for breaking up a dendritic structure.

QUESTION 53. What is the composition of the so-called semi-steel?

QUESTION 56. Which is the best method of producing large forgings, pressing or hammering?

QUESTION 57. Does repeated heating just above the critical range with subsequent quenching of a steel specimen injure its physical properties?

QUESTION NO. 58. What is the cause of brittleness resulting from the carburizing of steel?

ANSWER. Brittleness, when caused by faulty carburizing, is due to excessive concentration of carbon in the surface of the steel as the result of too high temperature, or the use of carburizers that are too "sudden." Some carburizers are not only too rapid in their action to be safe, but when analyzed show high percentages of sulphur and phosphorus; these elements are conducive to brittleness, are as easily absorbed as carbon, and, in fact, sulphur has been proven to be an effective "carrier" of carbon, performing the same function as carbon monoxide gas. It is well to watch carbonizers that contain a large percentage of coke, either Solvay or petroleum, as they nearly always contain large percentages of those two trouble-makers for the steel treater. The cause of checks, or cracks, in the surface of carburized steel (sometimes so small they can not be seen until the surface has been polished, and for that reason called "grinding cracks"), may be found in excessive carburization, or may be due to sulphur in the steel.

QUESTION 59. Is a sulphur content of 0.067 per cent detrimental to the proper carburizing of a low carbon steel having a low manganese and phosphorus content?

QUESTION NO. 60. What is the cause of distortion of carburized parts of regular conformations?

ANSWER. Distortion sometimes occurs in carburized parts of regular conformations, and apparently, with no accountable reason, but the reason exists, and is generally revealed when investigation discloses non-uniform carburization. For instance, some wristpins, approximately 6 inches in diamteer and 14 inches long, were carburized, and after heat-treating, were found to be $\frac{1}{8}$ inch shorter on one side. They were file hard all over, and after much theorizing it was decided to break one of them to discover the cause of the trouble. The fracture showed a very heavy penetration on one side while the other side had less than half as much. With a little observation the cause of the distortion in this case might have been discovered, and avoided, without breaking the pin. The pins were packed one in a pot and placed in a furnace in two rows. The furnace was so constructed that the hot gases from the combustion chamber below came into direct contact with the pots on one side while their other sides received the heat by radiation from the arch only; with the result that the pins were at a carburizing temperature hours longer on one side than the other, consequently uneven carburization occurred, and in the quenching the pins were pulled short on one side, and a large amount of material, besides time and labor, were utterly lost. Cracking and distortion are the most costly of all carburizing failures, and everything possible should be done to avoid them. Most of these failures may be avoided by giving careful attention to the uniform heating of the steel during carburizing and heat-treating.

Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Criticism in This Column—Members Submitting Discussions Are Requested to Give Their Names and Addresses

QUESTION NO. 36. Can mixed lots of steel be identified with a certainty by the aid of the grinding wheel spark test?

An answer to this question was published in the August, 1922 issue of TRANSACTIONS. The answer was an excerpt from a paper presented in Vol. II No. VI *Proceedings* of the Steel Treating Research Society, written by Prof. John F. Keller.

The following discussion of the answer to this question was recently received from Arthur S. Townsend, chief chemist of the Cleveland Twist Drill Co., Cleveland.

"The answer to question No. 36 in the August issue of the TRANSACTIONS, pages 1052-54, discusses at some length the spark testing of steel. This answer certainly must have been extremely interesting to all members of our Society who had ever made any previous study of this subject. The answer contains some real information on a subject which has only rarely been discussed in our technical literature and for this reason it is to be commended. It also contains some inaccurate statements which must be classed as misinformation. The color of the spark of high-speed steel for instance is not a "dark yellow," it is a dark red. The general explanation regarding the appearance of the various sparks is good and fully stated, but the meaning of some of the sentences is not clear, and some paragraphs are so worded as to be confusing, if not actually misleading.

"The chief objection to this answer, however, is that it implies that the spark test is a more valuable test than it actually is. The author is entirely too optimistic. Take this statement for example: 'To determine the quality by the spark analysis is not at all difficult if we have a known standard sample to compare with the metal under test.' As a matter of fact, it is actually often very difficult to determine 'the quality' in this way (even assuming that 'quality' here means kind). It is true that the spark test is useful occasionally for sorting out low and high carbon steels of a simple type, or for separating high-speed steel from carbon, but it is hardly correct to imply, as the author has done, that a miscellaneous collection of steels such as is listed on page 1054 can be sorted out by spark testing alone. It is also misleading to claim that the spark test can be successfully used to distinguish different brands of high-speed steel, one from the other.

"The spark test is crude, but it has the great advantage of being rapid and convenient. If pieces of steel of unknown composition are brought in for examination the first thing to try is the spark test, because this will very roughly classify the steel. If tools have been made from steel, the previous history of which is unknown, it is necessary before hardening to make use of either chemical analysis, thermal analysis or hardening tests—certainly something in addition to 'spark analysis.' The spark test is useful, but its limitations as well as its applications should be clearly understood."

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

SERVICE FOR MEMBERS

The Library Bureau of the American Society for Steel Treating is operated to give to the members quickly, reliably and at the minimum expense the following service:

1. A complete copy of the magazine article referred to in any periodical you may be reading.
2. A translation of foreign articles that would help you with your work.
3. A list of references to books and articles on any metallurgical subject.
4. Informing the members of new articles of interest to them as an engineer.

The Library Bureau makes the entire field of literature available to every member, distance is eliminated, for it will copy the desired information and send it to you. It also helps the busy man by supplying information without any expenditure of his time. The charge for this personal work is merely its cost.

The Library Service does not obtain any profit from the work, but does this to make the information contained in the large libraries with which it has connection available to every member. The rates are as follows:

Photo Print Copies of articles, drawings, etc., 25c per 10 x 14-inch sheets.
Searches, abstracts, etc., $2.00 an hour.
Translations, $6.00 per thousand words for French of German; $7.50 and upward for other languages.
Reference card service, giving reference to current magazine articles, $10.00 a year in advance, and 5c for each card mailed.

Members desiring to avail themselves of this service should address Library Bureau, American Society for Steel Treating, 4600 Prospect Ave., Cleveland, Ohio.

CASTING STEEL INGOTS CENTRIFUGALLY. By L. Cammen, in *Iron Age*, December 7, 1922.

This paper gives the results from using a horizontal bottleneck mold for centrifugally casting ingots and plate. It also compares this method with earlier processes. It shows the excellence of the ingots cast and gives their cost.

EQUILIBRIUM DIAGRAM OF THE IRON-CARBON SYSTEM. By Kotaro Honda, Bessemer Medalist, in *Chemical and Metallurgical Engineering*. Volume 27, No. 24, December, 1922.

The above is the sixtieth report, slightly abstracted, from the Iron and Steel Research Institute, Sendai, Japan.

In the diagram metastable or graphite lines are rejected, the solidus redrawn and A_4 or Delta iron fields are introduced. A_2 and A_0 represent no changes in phase, but are traced across the diagram.

EXPERIMENTAL PRODUCTION OF ALLOY STEELS. By H. W. Gillett and E. L. Mack, in *Journal* of Franklin Institute, Volume 194, No. 6, December, 1922.

The above is an abstract of notes from the U. S. Bureau of Mines.

The Bureau of Mines has prepared a number of series of alloy steels, containing such alloying elements as uranium, vanadium, tungsten, molybdenum, cerium, boron, and zirconium, alone and in various complex alloys. The steels prepared were studied with reference to the alloy recovery, the character and composition of the ingot, and their metallurgical behavior in the furnace. The Bureau of Standards and a number of commercial steel companies have co-operated in this work.

TOOL ENGINEERING. By Albert A. Dowd and Frank W. Curtis, President and Chief Engineer, Dowd Engineering Company, New York City, in *American Machinist,* Volume 57, No. 21, November, 1922.

This paper is the sixty-first installment of a series on tool design in which the subject of dies are treated.

Progressive piercing, blanking and double-bending dies are discussed.

DECARBURIZING FERROCHROMIUM BY HYDROGEN. By Louis Jordan and F. E. Swindells, Chemist and Assistant Chemist, Bureau of Standards, in *Chemical and Metallurgical Engineering,* Volume 27, No. 22, November, 1922.

Various tests have been made in connection with the preparation of this paper. These tests indicate that while the decarburization of ferrochromium by means of hydrogen takes place to some extent at temperatures below the melting point of the alloy, the most promising condition for refining high-carbon alloy by this method is probably by blowing the molten alloy with a blast of hydrogen in a converter.

ANNEALING OF GRAY CAST IRON. By Dr. E. Piwowarsky, of Breslau University in *Stahl und Eisen,* in September 28, 1922, republished in *Iron Age* Dec. 7, 1922.

The above paper gives the results in three tables of a German investigation of annealing tests on three grades of iron.

A PHYSICO-CHEMICAL INTERPRETATION OF THE EFFECT OF STRAIN UPON METALS. By C. Y. Yearsley, presented in October, 1920 before the Birmingham Metallurgical Society and published in the *Journal* of the Society in Vol. 8 No. 4.

This paper is the Students' Prize Paper and contains a review of the current literature on the effect of strain upon metals.

THE PROTECTIVE ACTION OF COPPER IN CASE CARBURIZING. By James C. McCullough (Associate Professor) and H. A. Holden Pray, of Severance Laboratory, Oberlin College, Oberlin, Ohio, in *Chemical and Metallurgical Engineering.* Volume 27, No. 23, December 1922.

The above paper shows the cause of failure in some cases and gives a reliable remedy.

When soft iron is heated in a charcoal pack, the carbon monoxide gas penetrates into the iron and gives up some of its carbon to the iron to effect the desired carburization. Carbon monoxide gas does not dissolve easily in copper and hence cannot pass through it unless there are cracks or holes in the copper. A thin copper plating over iron should, therefore, prevent carburization unless there are flaws in the copper.

The authors found flaws in every plating that they had examined that had failed to prevent carburization but no breaks were found in the effective platings.

STEEL. By Charles Rumford Walker. A book published by the Atlantic Monthly Press, Boston.

The author points out that in the great steel mills the 12-hour day and the 24-hour shift are still grim realities, but the men who toil there are not much given to analyzing their problems of living nor are they much gifted in the way of self-expression.

In STEEL, a college man who has worked as a clean-up in the pit, as helper on the open-hearth, and as hot flash man on the blast furnace, has raised a voice, not in plea nor in plaint, but in a straight broad shouldered story of his own life in the mills from day to day. It makes interesting reading from many points of view.

STANDARDIZATION OF SMALL TOOLS. By Carl J. Oxford, Chief Engineer, National Twist Drill & Tool Company, Detroit, Michigan, in *Mechanical Engineering,* November, 1922.

The above paper explains how the first cost of small tools can be greatly lowered, without sacrificing their efficiency, by the adoption of standards that will permit their manufacture on a quantity basis.

EFFECT OF MANGANESE ON CARBON STEEL. By Henry S. Rawdon and Frederick Sillers, Jr. in *Iron Age,* Nov. 23rd, 1922.

This paper shows how the structure of carbon steels is effected by varying percentages of manganese. While the results of the structure examination did not warrant any definite conclusion concerning the use of manganese as a strengthening element in steel, the results obtained, strongly supported previous recommendations which have been made by different metallurgists concerning the advantages to be gained from the use of higher manganese, particularly in lower and medium carbon steels.

An interesting application of a rather unusual alloy steel has come to light. In an address before the New York chapter of the American Society for Steel Treating, last week, a representative of one of the largest American companies producing steel castings and forgings for locomotive parts stated that his company is rapidly expanding its use of manganese-vanadium steel in forgings in place of plain carbon steel. The steel contains about 0.90 per cent manganese and 0.20 per cent vanadium. It has excellent physical properties, is superior to the plain carbon steel, lower in manganese than was formerly used, and is especially responsive to the heat treatment necessary for parts into which it goes. A similar steel, higher in manganese but without the vanadium, made a record during the war because of its unusual properties. Containing 1.25 to 1.50 per cent manganese, it must be regarded as an alloy steel. It is still in use, but its possibilities are not yet fully appreciated, thorough investigations of its behavior are actively in progress. With part of the manganese replaced by vanadium, this new alloy steel is an illustration of the many combinations possible and of the tendency of simple alloy steels to replace plain carbon steels.

DETERMINING COMBINED NITROGEN IN IRON AND STEEL. By Louis Jordan and F. E. Swindells, Chemist and Assistant Chemist, Bureau of Standards, in *Chemical and Metallurgical Engineering,* Volume 27, No. 23, December 1922.

The authors explain the Allen method for combined nitrogen and state that the usual method for the determination of combined nitrogen in steel is a modification of the Allen method.

They also point out the errors which result from the use of the Nessler method or rather the Nessler determination. Two tables are given showing the comparison of titration and Nessler methods as well as the comparison of methods of solution.

The paper finally explains the method for combined nitrogen which is used by the Bureau.

EQUIPMENT FOR MAKING DIE-CASTINGS. By A. G. Carman, Chief Metallurgist, Franklin Die-Casting Corporation, Syracuse, New York, in *Machinery*, December, 1922.

This paper is the first of a series of articles which points out the applications of die-castings; discusses the general principles of die-casting machines; and gives points on the design of parts to be die-cast.

The author is secretary of the Syracuse Chapter of the American Society for Steel Treating.

LAYOUT FOR ELECTRIC TOOL STEEL PLANT. By Merle W. Caruthers, Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, in *Iron Age*, Nov. 23, 1922.

This paper gives a suggested plan which represents an idea for the layout of an electric tool steel plant. The author states that we are slowly realizing that the physical requirements of any tool steel are far more important than the chemical composition. It remains for some standard testing apparatus to be designed that will reveal the true requirements of tool steel and, until that time comes, our greatest safeguard against poor quality is by using steels that have been made by up-to-date manufacturers, using up-to-date methods and equipment and controlled by up-to-date supervision and design.

MANUFACTURE OF ALLOY STEELS FOR AEROPLANE SHAFTS. Abstracted from *Stahl und Eisen*, Jan. 8th, 1920 and May 20th, 1920 published in *Chemical and Metallurgical Engineering*, Vol. 27 No. 21, November, 1922, by Dr. E. Kothny.

The author recounts his experiments on the manufacture of nickel-chromium steel in the basic Heroult electric furnace and comes to the conclusion that in order to produce aeroplane shafts, with no trace of transverse structure, it is necessary to use very good raw material and refine with two oxidizing slags as well as the usual carbide slag.

ELECTRIC HEATING APPLIED TO THE STEEL INDUSTRY. By F. A. Hansen, Combustion Engineer, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., in *Journal* of the Association of Iron & Steel Electrical Engineers, November, 1922.

The author describes the various types of industrial heating appliances, low temperature ovens, electric furnaces, stating that the electric furnace has reached a stage where it may be assumed that it can be applied to practically any process now accomplished through fuel-fired furnaces.

Reviews of Recent Patents

1,423,361. Device for Producing Extruded Sheet Metal. Albert F. Rockwell, Bristol, Conn., assignor to Marlin-Rockwell Corporation, New York, a corporation of New York.

This invention relates to apparatus for reducing metal ingots to sheet form. It has been discovered that several steps can be dispensed with in the ordinary process of reducing the ingot to sheet form, thus reducing quite materially the most of production, and in addition produce a sheet metal having greatly improved characteristics with relation to the quality of the metal in the final product.

1,424,171. Machine for Manufacturing Tubing. Dwight B. Lee, Detroit, Mich., assignor to Motor Products Corporation, Detroit, Mich., a corporation of Michigan.

This invention relates to the manufacture of metallic tubing of that type in which the tube is first formed up from sheet metal with a locked seam, the seam being soldered to effectually seal the same.

1,424,483. Drilling Machine for Tapping out the Hot Metal of Furnaces and Cupolas. Joseph E. Judy, McKeesport, Pa.

The above invention contemplates the provision of a drilling machine adapted to be operated by fluid pressure and to be suspended from a jib crane or other movable supporting element and swung into position in front of the tapping hole and held there during the drilling of the hole.

1,424,595. Casting Machine. Paul E. Schwarz and Thomas D. Salmon, Philadelphia, Pa.

This invention relates to devices particularly designed for making dental and similar castings, and one object of said invention is to provide a simple, reliable, comparatively inexpensive device for causing air pressure to be applied to a body of molten metal, with a view to causing this to flow into a suitably positioned mold.

1,425,111. Alloy for use in Electric Heating Appliances. Geo. Harry Lofts, Hobart, Tasmania, Australia.

This invention relates to the manufacture of an alloy that was found especially useful in electric-heating appliances for the protection of same. In such appliances a fusible metal has been employed to cut off the power or current in order, for instance, to avoid over-heating.

1,425,499. Heat-Treating apparatus. Harry A. Lewis, Norristown, Pa.

In heat treating apparatus the combination of a furnace having a false bottom, a plurality of rows of slots formed in the said false bottom, shafts mounted beneath the said rows of slots and transversely to the individual slots, means for rotating the said shafts, and disks eccentrically mounted on the said shafts and adapted when the said shafts rotate to project up through the said slots and to directly engage and support the work during a portion of their movement, the

disks on each shaft being set alternately at two different angles on their shaft, and the disks on each shaft being staggered with relation to the disks on the adjoining shafts.

1,425,660. Furnace for the heat treatment of metals. Lyman C. Josephs Jr., Allentown, Pa., and Gottfried Wirrer, Plainfield, N. J., assignors to International Motor Company, New York City.

In a furnace for the heat treatment of metal, the combination of a series of heat treating stations, a carrier movable to transfer the article under treatment from one station to the next, a motor for operating the carrier, electrical connections through which the motor is operated intermittently and devices subject to a change in the rate of change of dimension of the article under treatment whereby the operation of the motor is initiated after each period of rest.

1,425,851. Metal-Treating Apparatus. John F. Gillan, Schenectady, New York, assignor to General Electric Company, a corporation of New York.

The invention comprises an improved apparatus for carrying out metal coating processes, and particularly the process known as sherardizing, which involves the surface alloyage of a metal with zinc.

1,427,121. Heat treatment of manganese steel. Wesley G. Nichols, Chicago, Ill., assignor to American Manganese Steel Company, Chicago, Ill.

The invention relates to an improvement in the art of heat treating manganese steel castings, which consists in subjecting such castings to heat, the maximum temperature of which never exceeds the critical temperature for such castings.

1,427,753. Method of annealing metal. Edward G. Budd and Joseph Ledwinka, Philadelphia, Pa., assignors to Edward G. Budd Manufacturing Company, Philadelphia, Pa.

The method of annealing metal which consists in enclosing the part to be annealed and removing therefrom the oxidizing effect of the surrounding medium, and including the same in series in the secondary circuit of an electrical transformer to heat the same to an annealing temperature, and finally cooling such part before exposure thereof to oxidizing influences.

1,430,948. Electrical Furnace for Treating Ores. Agamemnon Counas, Paris, France.

This invention relates to an electric furnace for treating ores, comprising a rectangular vat, a charging hopper above the vat, inclined electrodes on each side of the hopper and extending into the vat, the number of the said electrodes being determined by the length of the said vat, and a return electrode forming part of the hearth of the furnace, and arranged directly below the hopper.

1,435,211. Electric furnace. O. A. Colby, of Irwin, Pennsylvania, assignor to the Westinghouse Electric & Manufacturing Company of East Pittsburgh, Pa.

The invention relates to a crucible furnace, wherein the crucible is built up of alundum, sintered in place, resting on a resistor made of carborundum blocks. Current is led in by massive graphite blocks. Contacts at each end of the carborundum resistor are made by a packing of granular graphite, periodically replenishing that which is burned. The essential parts of the furnace are encased in refractory firebrick and insulating material, the whole bound with steel plates and mounted on trunnions.

News of the Chapters

SCHEDULED REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Boston—Second Tuesday
Bridgeport—Thursday between 20th and end of month
Chicago—Second Thursday
Cincinnati—Second Thursday
Cleveland—Fourth Friday, Cleveland Engineering Society Rooms, Hotel Winton; meeting at 8:00 p. m.
Detroit—Second and fourth Monday. Detroit Board of Commerce.
Hartford—Friday nearest 10th of month
Indianapolis—Second Monday
Lehigh Valley—No regular night
New Haven—Third Friday
New York—Third Wednesday
Philadelphia—Last Friday
Pittsburgh—First Tuesday
Providence—No regular night. Nov. 10th, Dec. 12th.
Schenectady—Third Tuesday
Springfield—Third Friday
South Bend—Second Wednesday
St. Louis—Third Monday
Syracuse—No regular night
Tri City—Thursday
Washington—Third Friday
Rockford—Second Friday following the second Thursday

STANDING OF THE CHAPTERS

During the month of November, 73 new members were added to the Society as compared with 166 new members for the month of October. This increase in new members is a pleasing indication of the activities of the chapters, and while it is lower than the number obtained for October, it is realized that about 70 applications for membership were obtained at the annual convention. The 73 new members were distributed among 20 of the chapters, Detroit obtaining the largest number (16) while North West and Philadelphia obtained the second largest (9 each) and Chicago obtaining (8) of that number.

Detroit is still the largest chapter in the Society, having a lead of 46 members over its nearest competitor, Chicago. The standing of the chapters is as follows:

Those printed in capitals have advanced their position. Those

printed in italics have lowered their position from that published in the November report.

1. Detroit
2. Chicago
3. Pittsburgh
4. Philadelphia
5. Cleveland
6. New York
7. Hartford
8. Milwaukee
9. Boston
10. Lehigh Valley
11. NORTH WEST
12. **Syracuse*
13. **Worcester*
14. **Indianapolis*
15. *ST. LOUIS
16. *Rockford*
17. Tri City
18. *Cincinnati*
19. Buffalo

*=Tied

20. *Washington*
21. SCHENECTADY
22. **Springfield*
23. **Providence*
24. New Haven
25. South Bend
26. Toronto
27. Rochester
28. Bridgeport

*=Tied

Several suggestions have been received that some of the smaller chapters located in towns having a population of one hundred thousand or less, are not particularly interested as to the standing their chapters may have as compared with Detroit, Chicago, Pittsburgh and Philadelphia, and while it is realized that their point is well taken, and that under no conditions are the possibilities such that they would be able to rank first, second, third or fourth, nevertheless, it is felt, after giving the matter serious consideration, that it is advisable to continue the monthly report as to the standing of the chapters on the basis of membership. If any division is made, according to the population, it would be an injustice to some of the chapters having a large number of inhabitants whose industrial community is not as largely devoted to the iron and steel products as are the industries of a town of smaller number of inhabitants.

Thus it seems that inasmuch as the standing of the chapters is given only for a comparative basis and to create interest in the proximity of one chapter to another, it does not seem proper to undertake a classification according to population. The only justifiable re-arrangement would be in groups according to the industries and possibilities of the chapter in each city, and in order to do that it would be necessary to have a survey made of each city, which is more or less impossible.

Attendance Contest

The attendance contest does not begin until the December meeting and consequently no attendance percentage was possible for the January issue. However, the February issue will contain the percentage of members in attendance at the December meeting.

In this regard it is pointed out that the percentage of members in attendance is not based upon the number of members in good standing on Sept. 1, but is based upon the number of members in good standing on the first of EACH month. In other words, the percentage of members at the December meeting is not based upon the September number, but is based upon the number of members in good standing on Dec. 1.

The standing of the various chapters will then be considered on a basis of 50 per cent for attendance and 50 per cent for increase in membership. As an example, if a chapter had a percentage increase in membership of 46.2 per cent and an attendance percentage of 23.4 per cent, the total percentage 69.6 per cent would then be divided by 2, which would give the chapter a combined standing of practically 35 per

cent. All members of all chapters are urged to attend their regular monthly meeting, so that their attendance will count as an increase in percentage in the contest.

Increase in Membership

The National office has notified all of the chapter secretaries the number of members each had in good standing on Sept. 1, 1922 and has compiled from the monthly report sent to the local officers the new members the chapters have secured since that date up to Dec. 1, 1922 and has then figured the percentage of increase each chapter has had since Sept. 1. As an example, if a chapter had 90 members on Sept. 1 and gained during the months of September, October and November, 4 new members then the percentage increase would be 4.5 per cent, or, if the chapter had 25 members in good standing on Sept. 1 and during the interval up to Dec. 1 gained 6 new members, then their increase would be 24 per cent. The following shows the percentage of increase in membership on Dec. 1 over the chapter membership on Sept. 1, 1922.

	Per Cent		Per Cent		Per Cent
1. Detroit	46.2	10. New York	14.2	19. Pittsburgh	5.7
2. North West	28.3	11. Buffalo	12.5	20. Indianapolis	5.4
3. South Bend	24	12. Cleveland	10.8	21. Springfield	5.1
4. Schenectady	20.6	13. Chicago	9.7	22. Hartford	4.5
5. Milwaukee	18.3	14. Cincinnati	9	23. Syracuse	3.6
6. Boston	18.2	15. Washington	7.5	24. Toronto	3.6
7. Lehigh Valley	16.7	16. Worcester	7.2	25. Bridgeport	..
8. Philadelphia	15.5	17. Rockford	6	26. Providence	..
9. Tri City	14.6	18. New Haven	6	27. Rochester	..
				28. St. Louis	..

DR. ROSENHAIN TO TOUR AMERICA

THE eminent metallurgist, Dr. Walter Rosenhain, chief of the metallurgical department of the National Physical Laboratory of Great Britain and widely known for his capable research work, will tour the eastern part of the United States during February and March, 1923. On this tour he will lecture to various universities and educational institutions and technical societies.

The subjects of his lectures will be: The Structure and Constitution of Alloys; Aluminum Alloys; Hardness and Hardening; Strain and Fracture in Metals; Metallurgical Researches at the National Physical Laboratory.

"Solid Solutions" will be the title of the second annual lecture before the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineering. This subject will deal with theoretical and fundamental principles.

He will deliver his lecture entitled "The Structure and Constitution of Alloys," before the Franklin Institute and will probably deal with the constitutional or equilibrium diagrams of alloy systems, their experimental determination and their interpretation.

It has not been definitely announced which of the lectures will be pre-

sented at the other meetings as listed below. For information in addition to this and pertaining to Dr. Rosenhain's visit may be secured from W. M. Corse, National Research Council, Washington, D. C.

Dr. Rosenhain's itinerary is as follows:

Lehigh University, Bethlehem, Pa., Feb. 14 to 16; Franklin Institute, Philadelphia, Feb. 15; American Institute of Mining Engineers, annual meeting, New York, Feb. 19 to 23, where he will speak at the banquet, Feb. 21, and deliver the second Institute of Metals lecture on Feb. 20 or 21; Columbia University, New York City, Feb. 23; Yale University, New Haven, Conn., Feb. 26 to 28; Waterbury, Conn., March 1 and 2; Providence, R. I., March 3; Massachusetts Institute of Technology, Cambridge, Mass., March 5, 6 and 7; Schenectady, N. Y., March 8 and 9; Rome or Corning, N. Y., March 10; Case School of Applied Science, Cleveland, March 12 and 13; Detroit, Mich., and Ann Arbor, Mich., March 14 to 19; University of Illinois, Urbana, Ill., March 20 to 22; Chicago, March 23 and 24; Toledo, O., March 26; Huntington, W. Va., (International Nickel Co.), March 27; Charleston, W. Va., March 28; Pittsburgh, March 29 and 30; Washington, D. C., March 31 to April 4 or 5; New Haven, Conn., dedication meeting of the American Chemical society.

INDUSTRIAL ENGINEERS ORGANIZED

AS ANNOUNCED in the current issue of *Gas Age Record,* several very definite undertakings for the industrial branch of the gas business have been outlined by the managing committee of the commercial section of the American Gas association. E. J. Stephany of the Equitable Gas Co., Pittsburgh, has been made chairman of the Industrial Gas committee, which may later be called the Industrial Gas division. The personnel of the committee, as just announced, includes many of the most prominent industrial gas engineers in the industry. They are:

N. T. Sellman, industrial engineer, A. G. A. Staff.
E. D. Milene, Consolidated Gas, Electric Light & Power Co., Baltimore.
W. T. Rasch, Consolidated Gas Co., New York.
H. H. Clark, Peoples Gas Light & Coke Co., Chicago.
F. F. Cauley, Peoples Gas Light & Coke Co., Chicago.
H. H. Smith, Boston Consolidated Gas Co., Boston.
H. O. Lobell, Combustion Utilities Corp., New York.
H. M. Henry, Combustion Utilities Corp., Toledo.
J. P. Lanroth, Public Service Co. of New Jersey, Newark, N. J.
John B. Allington, Rochester Gas & Electric Corp., Rochester, N. Y.
A. A. Schuetz, Milwaukee Gas Light Co., Milwaukee.
Robert E. Ramsey, the U. G. I. Co., Philadelphia.

Plans contemplate giving the committee ample time at the annual convention of the association for the discussion of the many problems confronting the industrial gas man today, when every indication is that soon the greatest outlet for the product of the gas plant will be for industrial uses. The committee will be allotted time for parallel sessions with the commercial section if necessary to cover the ground desired.

One definite aim of the committee for this year will be to try to interest

many makers of industrial equipment to exhibit at the annual A. G. A. Appliance and Equipment show and to encourage them also to display their apparatus and devices at other conventions where fuel and industrial process are considered. Several members of this committee are members of the American Society for Steel Treating.

BOSTON CHAPTER

The Boston chapter of the society held its regular December monthly meeting Thursday evening, December 14, at 7:30 p.m. in the Massachusetts Institute of Technology, testing material laboratory. Dr. G. B. Waterhouse, Professor of Metallurgy, formerly of the Lackawanna Steel Co., presented a very interesting paper entitled "Basic Open-Hearth Steel." Dr. Waterhouse's paper proved to be highly interesting and instructive and following it a lively and interesting discussion was held.

The laboratory of Professor Cowdrey and Mr. Homerberg were open for inspection, and members and guests were privileged in seeing many of the testing machines in operation, and also many samples of steel and photomicrographs of them were on display.

As evidenced by the large number of members and guests in attendance, this meeting was a decided success.

The January meeting will be held at the Blake & Knowles plant. The subject of the paper for this meeting will be "Forging." The plant of the Blake & Knowles company will be in actual operation, the exhibition will include the making of crank shafts and miscellaneous engine forgings, also the forging of Monel metal and bronze. A demonstration of the acetylene cutting torch and its advantages in forge practice will also be given.

CHICAGO CHAPTER

The Chicago chapter of the society held its regular meeting December 14, in the rooms of the Chicago City club, Plymouth Court and Jackson boulevard. The usual get-together dinner was served at 6:30 p.m. in the club rooms.

The program for this meeting was handled by three speakers.

Inasmuch as the Chicago chapter has used a novel method of announcing this meeting, we are publishing their program as they announced it in their leaflet, as it tells the whole story of their December 14, meeting. The announcement is a novel one and due credit should be given to the author of the idea.

AMERICAN SOCIETY FOR STEEL TREATING
CHICAGO CHAPTER

The Time

Thursday evening at 6:30 p.m. Dec. 14, 1922.

The Place

Chicago City club, Plymouth Court and Jackson Boulevard.

The Program

The next time your chairman rattles the bent spoon against the water

bottle, he will announce the subject of the evening to be none other than

How Would You Do It?

How would you do what? What would a steel treater naturally like to do? There are many things that steel treaters like to do, but there is one thing that every steel treater must do besides blame the steel for his troubles and that is heat his furnaces. He must therefore choose between gas, oil or electricity.

The presentation of this vital subject will be divided into three rounds of thirty minutes each.

At the sound of the first gong, W. P. Squire of the W. S. Rockwell Co., will tell us all there is to know about the use of oil for heat treating.

At the sound of the second gong, V. A. Hain of the George J. Hagan Co., will do likewise with electricity.

At the sound of the third gong, R. G. Guthrie of the Peoples Gas Light and Coke Co., will kick in with like information on the use of gas for heat treating.

Your committee can assure you that proper combustion will take place in each round without excess scaling, due to too much excess air. Mr. Hain on the electric end, don't use excess air so he must have something on Squire and Guthrie on that score.

Following the main bout there will be a catalytic discussion of same. Catalytic in that it will serve to jazz up many reactions in our minds and cause us to ask a multitude of questions.

Bring Your Appetites Along

Preceding the verbal barrage, dinner will be served at the City club, Plymouth Court and Jackson Boulevard, promptly at 6:30 p.m. There will be no baked ham and beans, but on the other hand there will be a real steak dinner with all the trimmings that Mr. Volstead will allow. The price of this feed will be the regular $1.25 per plate, your chapter absorbing the extra cost.

Reservations

Members are requested to send in their reservations cards at once as there will be big attendance. Otherwise they are going to have to eat by themselves.

CINCINNATI CHAPTER

The regular meeting of the Cincinnati chapter was held Thursday evening, Dec. 14, at 8:00 o'clock in the Ohio Mechanics institute, Canal and Walnut streets. The speaker for this meeting was Owen K. Parmiter, metallurgist, Firth-Sterling Steel Co., who presented a very capable paper entitled "Stainless Steel." Mr. Parmiter has presented this paper before several of the chapters and it has proved of great interest to all who have had the privilege of hearing him. There has been a great deal of interest shown in the rust-resisting steels and Mr. Parmiter handled his subject in a very capable way. A lively and interesting discussion followed this paper.

The January meeting of the chapter will be held on the eleventh of the month at which time W. R. Klinkicht, assistant engineer of tests, of the Pollak Steel Co., will present a paper entitled "The Forging of Large Sections." This paper will be illustrated with stereopticon views.

The February meeting will be held on the eighth of the month at which time, E. E. Thum, associate editor of *Chemical & Metallurgical Engineering* will present a paper entitled "The Relation Between the Management and the Metallurgist."

CLEVELAND CHAPTER

The Cleveland chapter of the society helds its regular monthly meeting on Dec. 20, at 8 p.m. in the Cleveland Engineering Societies rooms, Hotel Winton. The meeting was preceded by the usual get-together dinner which was served at 6:30 p.m. in the English room of Hotel Winton.

The chapter was particularly fortunate in being able to secure as speaker, Marcus A. Grossmann, metallurgist with the Atlas Steel Corp., Dunkirk, N. Y., and formerly with the United States bureau of standards who presented a very interesting and instructive paper entitled "Alloying Elements in Steel." Mr. Grossmann outlined in considerable detail the effects of varying quantities of the numerous alloys which are used in the manufacture of steel after suitable heat treatment had been given them as well as in their normal state. Mr. Grossmann developed his subject in a very clear and logical manner. A lively and interesting discussion followed the presentation of the paper.

One of the important matters which came before this meeting was that pertaining to a proposed bill for the licensing of Ohio engineers. This matter is receiving the careful attention of all engineers in the state of Ohio, inasmuch as two years ago a bill had been presented before the Ohio legislature and through the efforts of many of the engineers in the city of Cleveland and elsewhere in the state they succeeded in having the bill temporarily dropped inasmuch as they believed that it was not a bill which was for the best interests of all concerned.

Following a meeting of the Associated Engineering Organizations of Ohio, which was held in Columbus, O., Dec. 9, a questionnaire was prepared and sent out to all engineering organizations of the state. The questionnaire outlined three plans for registering engineers and it was requested that each engineering club, section chapter or society signify just how they would vote on any one or all of these plans.

Plan A. Provides for Compulsory Registration.

This plan is the one contained in the bill suggested by the Ohio Assembly A. A. E. and is a general bill to cover all engineers in the state in responsible charge of the design and construction of engineering work of a public or private nature which involves the public welfare, safety or health. The real intent of the plan is that all qualified and responsible engineers and surveyors in the state must or ought to be registered.

Plan B. Provides for Limited Registration.

This plan is the one contained in the bill suggested by the Council of Associated Technical Societies of Cleveland and is a special bill to cover only one class of engineers, namely, those employed by the state, countries, cities and other political subdivisions of the state. The real intent of the plan is, that all engineers other than those engaged on public work shall be exempt from registration but that the exempt ones may become registered if they so desire.

Plan C. Provides for Optional Registration

This plan is the one suggested at the meeting on Dec. 9 and is

an open bill to cover all engineers and surveyors in the state who desire to be registered of their own free will. The real intent of the bill is that no one must be registered. It is thought that if some engineers and surveyors become registered then in time all other engineers and surveyors will desire to be registered for reasons of professional pride and standing.

The chapter went on record as favoring plan B and instructed the secretary to advise the Associated Engineering Organizations of Ohio as to the manner in which the chapter has voted. The vote of the chapter will count as one ballot which will be considered together with those of the societies at the time of the executive committee meeting of the A. E. O. O. on Dec. 29. The result of this ballot will determine the future procedure of the A. E. O. O. in reference to the proposed bill for licensing engineers.

The legislative committee of the Associated Technical Societies of Cleveland of which the chapter is a member has drawn up a proposed Ohio registration bill for professional engineers and land surveyors which contains most of the provisions of the A. A. E. proposed bill but which eliminates the features that were objectionable to the Cleveland engineers. It provides for limited registration of engineers and the real intent of the plan is that all engineers other than those engaged on public work shall be exempt from registration but that the exempt ones may become registered if they so desire.

The entire matter is in the hands of the legislative committee of the Associated Technical Societies of Cleveland and the committee has been given full authority to act at such times as they are called upon.

DETROIT CHAPTER

The Detroit Chapter is going through a period of boom. No noisy revival is being raised. It is not artificial. Apparently no more efforts are used than usual, still the members are flocking to the meetings.

At the Nov. 27 meeting of the chapter E. J. Janitzky of the Illinois Steel Company read a paper on "Melting Practice, Open-Hearth, Bessemer and Electric. Mr. Janitzky made his paper especially interesting by illustrating the processes with motion pictures, taken at the Illinois Steel Company's plant.

The chapter had as its guest W. S. Bidle, second vice-president of the Society and Professor A. E. White, a member of the Board of Directors. These two members of the Board of Directors were present to discuss some matters pertaining to the local chapter, and the National Society in general.

The Detroit Chapter feels quite proud of the interest its members are taking in the Society's affairs. To further this, and to make the members better acquainted with each other, the chapter plans to have every second meeting connected with a supper, and all meetings will be held at the Board of Commerce as they were last year, where the members can enjoy a little more comfort, than in some of the meeting rooms in which they have had their meetings during the present year.

On Monday, Dec. 11 the chapter held a meeting in the Board of Commerce room at which time Earl C. Smith, metallurgist of the Cen-

tral Steel Company of Massillon, Ohio, presented his very capable paper entitled "Rolling Practice—Ingot to Finished Product." This subject has created considerable interest, and Mr. Smith presented his subject in a very capable manner. The paper brought out some very interesting and valuable discussion which was participated in by many of the members present.

Following the dinner which preceded the meeting, R. R. Plum was presented with a traveling bag as a token from the members of the chapter for his invaluable services during the convention when as a member of the financial committee he sacrificed many days to make the convention a financial success.

HARTFORD CHAPTER

The December meeting of the Hartford chapter was held Friday evening, Dec. 8, at 7:45 in the assembly hall of the Hartford Electric Light Co., Hartford, Conn. An informal dinner was served in the Young Men's Christian association cafeteria downstairs at 6:30 p. m. preceding the meeting, which was attended by a considerable number of members and guests.

The program for this meeting consisted of two papers, the first by G. C. McCormick entitled "Furnace Atmospheres and Their Relation to the Formation of Scale," and the second by E. L. Willson entitled "Synthetic Pig Iron."

The first paper described the experiments carried out at the Crompton Knowles Loom Works, Worcester, Mass., for the purpose of determining the conditions under which scale forms during the heat treatment of steel, and to determine methods of minimizing scaling. The subject of scaling steel has been a matter of considerable importance to steel treaters inasmuch as the scaling of finished tools is a very important and often times a serious proposition. Mr. McCormick's paper was very well presented and proved to be of extreme interest to all who were present, and developed a very lively and interesting discussion.

Mr. Willson presented his paper entitled "Synthetic Pig Iron" in which he gave a brief description of the conversion of steel scrap into pig or cast iron, as performed at the plant of the Connecticut Electric Steel Co. The process which he described is the reverse of that by which the original steel was made, and proved to be of particular interest because of the wide variety of compositions for special purposes which can be obtained by the electric furnace method of making cast iron. The discussion which followed Mr. Willson's paper was very instructive and interesting.

INDIANAPOLIS CHAPTER

The regular monthly meeting of Indianapolis Chapter was held Dec. 11 in the ald auditorium of Manual Training high school. The subject presented at this meeting was "Refining Steel by the Bessemer Process." This subject was presented in an excellent way by Mr. A. E. Crockett, of the Jones & Laughlin Co., of Pittsburgh. Mr. Crockett's paper covered the whole process from ore to finished product and was made more interesting by means of illustrations by lantern slides. Mr. Crockett's paper was one of the most interesting ever presented before Indianapolis Chapter.

The subject of the evening class in metallurgy held under the auspices

of the local chapter was brought up and enrollment was made. The classes are to begin Jan. 8 and will cover a period of 15 weeks, one night a week. Fifty-one enrolled at the meeting while several have signified their intentions to join before the next meeting. The course is under the direction of Mr. H. B. Northrup, metallurgist of the Diamond Chain & Mfg. Co., of Indianapolis. Mr. Northrup is especially well qualified to direct this course because of his extensive experience in the making of steel, having worked in all the different processes from mines to finished product and also because of his several years teaching experience on the same subject at Pennsylvania State college. The members of the local chapter will assist Mr. Northrup on special subjects.

The meeting was attended by approximately 85, including several visitors from out of the city. Col. A. E. White of the board of directors attended the meeting as well as an executive meeting held before the general meeting.

The next meeting of Indianapolis Chapter will be held at the Citizens Gas Co., where an inspection trip will be held. After seeing how gas and coke are made, a dinner will be held, probably at the Hoosier Athletic club.

LEHIGH VALLEY CHAPTER

The Lehigh Valley chapter of the American Society for Steel Treating held its December meeting on the 5th at 8:20 p.m. in the clubhouse of the Ingersoll-Rand Co. The program for this meeting consisted of moving pictures, the first set of which was entitled "The Story of Rock Drilling"—showing the various methods and types of drill used in the quarrying of rock. The second series of pictures was that of "The Rolling of Armco Iron" showing the entire operation of the manufacture of Armco Iron at the plant of the American Rolling Mills Co., Middletown, O. The third series was entitled "The Story of the Manufacture of an Automobile" which was taken at the plant of the Studebaker corporation, South Bend, Indiana, showing the entire manufacture of the Studebaker Co.'s Light-Six car. These pictures were indeed very interesting and were enjoyed by about 100 members and guests.

Prior to the exhibition of the moving pictures, a great many indulged in bowling on the alleys of the club room.

Preceding the meeting proper, the members of the executive committee assembled at the University club with Mr. J. J. Crowe, member of the national board of directors to discuss matters pertaining to the local chapter and the national society.

MILWAUKEE CHAPTER

The Milwaukee Chapter of the American Society for Steel Treating held its December meeting on Thursday evening, the fourteenth at eight o'clock in the Medford Hotel, 119 Third St., Milwaukee, Wis. The meeting was preceded by a get-together dinner which was scheduled for seven p. m. Following this dinner, H. G. Knowlton, Instructor in Metallurgy, Milwaukee Continuation School, presented his very capable paper entitled "Carburizing." Mr. Knowlton who is an authority on carburizing presented some very pertinent facts pertaining to the process of carburizing steels. His paper was indeed interesting and brought forth some valuable

information to steel treaters. Following Mr. Knowlton's paper an interesting discussion on carburizing followed.

NEW HAVEN CHAPTER

The New Haven Chapter of the Society held its December monthly meeting Friday evening Dec. 15, at eight o'clock in the Assembly Room of the New Haven Gas Light Company, 70 Crown St., New Haven, Conn. Due to the inclement weather a number of the chapter members were unable to attend, although a fairly large number of members and guests were there to greet the speakers of the evening.

The subject which had been selected for this meeting was the selection of fuel for industrial heating operations and two very capable men had been selected to present this subject. The speakers were J. A. Doyle of the W. S. Rockwell Company, New York City, who presented his paper entitled "Selection of Fuel for Industrial Heating Operations" and E. F. Collins of the General Electric Company, Schenectady, N. Y. who spoke on the subject "Electricity as a Fuel."

This meeting was one of the most enthusiastic ones that New Haven Chapter has ever had, and a great many questions were asked from the floor after the speakers had presented their papers. It was regretted that more of the members of the chapter were not able to be there but it was due entirely to the bad weather conditions which prevailed during the day and evening of this meeting. Those who were in attendance surely enjoyed a very entertaining and instructive evening.

The New Haven Chapter is taking an active interest in the membership and attendance prizes which have been offered by the National Board of Directors of the Society and they are bidding well to be one of the recipients of one of the prizes to be awarded after June 30, 1923.

NEW YORK CHAPTER

On Wednesday evening, Dec. 20, the New York chapter enjoyed a very interesting and instructive paper entitled "Case Hardening" by C. B. Callomon of the Driver-Harris Co., Harrison, New Jersey. Mr. Callomon's paper proved very interesting and was enjoyed by many members and guests of the chapter. Following the paper a lively discussion in reference to case hardening and carburizing was held. The meeting proved to be very entertaining and instructive to all who were present.

NORTH WEST CHAPTER

On Tuesday evening, Nov. 28, the North West chapter held a smoker in the rooms of the Manufacturers' Club of Minneapolis. This meeting was a get-together meeting. There was no specific program outlined, but this meeting was held to give the members an opportunity to meet their old friends and also to meet the newer members. The evening was devoted to good music, moving pictures, and various kinds of interesting entertainment. Refreshments were served and a goodly quantity of smokes were available.

This meeting was well attended and proved to be a decided success.

The North West chapter held a meeting on Tuesday evening, December 12, in the rooms of the Manufacturers' club of Minneapolis. J. Fletcher Harper, research engineer of the Allis-Chalmers Manufacturing com-

pany, Milwaukee, presented a paper entitled "Practical Experiences with Deep Etching and Annealing of Cast Iron and Forgings." Mr. Harper illustrated his paper with stereopticon slides. The speaker who formerly was assistant superintendent of forgings with the Allis-Chalmers Manufacturing company and who is now research engineer for the same company has had many varied and practical experiences which formed the basis of his paper. Mr. Harper pointed out the advantages of the deep etching method for the examination of material for machinery parts; and pointed out that defective material could be quite readily detected by this method of examination. The portion of his paper dealing with the annealing of gray iron castings proved of considerable interest to all, due to the fact that the ageing or annealing of iron castings is quite an important feature to be observed prior to the machining of parts such as pistons and cylinder-blocks inasmuch as many have found that in machining gray iron castings without annealing or ageing them, there has been caused untold trouble in the finished product due to the fact that the castings will not stay in shape. Mr. Harper presented some very valuable and interesting data on the subject.

PITTSBURGH CHAPTER

The regular monthly meeting of the Pittsburgh chapter of the society was held jointly with the American Institute of Mining and Metallurgical Engineers Tuesday evening, Dec. 5 in the Chatham hotel roof garden. I. J. Anderson of the United States bureau of mines, presented a paper on "Corrosion," which reviewed considerable of the work that the bureau of mines is doing on this particular subject. Mr. Anderson presented some very interesting facts with reference to the corrosion of metals and his paper was indeed interesting and instructive to all.

The second paper of the evening was presented by Prof. S. L. Goodale of the University of Pittsburgh, entitled "Metallurgical Education." The usual get-together dinner was served at 6:30 in the Chatham hotel.

PROVIDENCE CHAPTER

The Providence chapter held its December meeting in the fuel laboratory of the Providence Gas Co. This was the first meeting of the membership attendance contest. There were many prospective members among the 130 present.

The subject of the meeting was "The Proper Heat Treatment of High-Speed and Carbon Tool Steel" presented by Z. N. Sault of the New England Annealing & Tool Co.

Arthur H. Higgins, sales manager of the Providence Gas Co., also gave a short address on the subject of "Heat" bringing out the idea that heat was necessary to produce everything that we used either at home or in our industrial lives. He then told of the part that gas played in the production of this useful heat and the economy of fuel in first turning the coal into gas so as to get all the by-products such as ammonia, tar, perfumes, extracts, etc.

The meeting took the form of a demonstration and lecture, Mr. Sault first giving a demonstration of the proper method of hardening high-speed

steel using furnaces heated by gas furnished by the Providence Gas Co. and quenching the steel in oil.

He also made the Metcalf test to determine the best hardening temperature for a piece of 1.20 per cent carbon steel.

Both the demonstrations were highly successful.

The audience then retired to the lecture room where Mr. Sault explained more fully the methods he used and gave a lecture on steel, explaining many methods of heat treatment which he had found successful during his 30 years' experience at the fire.

The speaker then answered several questions and there was a lively discussion on some of the points brought out by his lecture.

Mr. Sault is one of the "Men at the Fire" as well as a successful business man and his talk was very helpful and educating to all present. This meeting will be followed next month by a talk on the proper use of pyrometers to be given by Mr. McCormick of the Crompton Knowles Co., of Worcester. The Providence Gas Co. further helped the success of the evening by furnishing smokes and refreshments.

SCHENECTADY CHAPTER

The Schenectady chapter of the society held a meeting on Nov. 21 at Union college at which time Mr. R. B. McColl, assistant general manager of the American Locomotive Co., presented a very interesting paper entitled "Relation of Steel Worker to the Management." Mr. McColl's paper proved to be very interesting and resulted in a lively round-table discussion following. There were about 60 members and guests present and everybody enjoyed themselves heartily.

SPRINGFIELD CHAPTER

Mr. E. E. Thum, associate editor of *Chemical and Metallurgical Engineering* addressed the chapter on Friday evening, Dec. 15, at 8 o'clock in the Chamber of Commerce building. The subject of Mr. Thum's paper was "Educating the Metallurgist and Management." The paper proved to be very interesting and was a very capable presentation, as Mr. Thum has had many years of experience in industrial problems and has been associated with both phases of his subject for many years. A very interesting and instructive discussion followed his presentation.

WORCESTER CHAPTER

The Worcester chapter of the American Society for Steel Treating held its December meeting, Thursday evening, the fourteenth in the Electrical Lecture room at the Worcester Polytechnic Institute, Salisbury street, Worcester, Mass. The paper for this evening entitled "Educating the Metallurgist and the Management" was presented by E. E. Thum, associate editor, *Chemical & Metallurgical Engineering.* Mr. Thum presented his paper in a very entertaining and capable manner and it proved to be of extreme interest to all those who were present. This meeting was a joint meeting with the Worcester section of the American Society of Mechanical Engineers.

ST. LOUIS CHAPTER

The St. Louis chapter of the American Society for Steel Treating held its December meeting on the eighteenth at 8 o'clock in the American Annex hotel. The speaker for this evening was Ellis M. Johnston, district manager of the American Rolling Mill Co. of Middletown, O. His paper entitled, "Manufacture of Armco Ingot and Special Steel," was illustrated with three reels of moving pictures, taken at the plant of the company Mr. Johnston represents. These pictures show the manufacture of the product of the American Rolling Mill Co., from the ore to the finished product. Mr. Johnston presented his paper in a very capable and interesting way.

Prior to the meeting proper, a get-together dinner was served at 7 o'clock in the rooms of the American Annex hotel.

SOUTH BEND CHAPTER

The December meeting of the chapter was held at the Hotel LaSalle. Dinner was served at 6:30 p.m. at the College Inn, Hotel LaSalle to 27 members and guests. Following the dinner those present, needing a walk to settle their meal, walked up two flights of stairs to the meeting room.

Announcement was made that the speakers for the January, February and March meetings had been arranged.

A very interesting discussion was held on W. J. Harris' paper entitled "Some Factors Governing the Machineability of Steel," read at the November meeting.

W. F. Newhouse, a member of the chapter, read a paper on the subject "Heating Carbon Steel Parts—Lead Bath Method."

A very lengthy discussion was held on this paper, which was very interesting and instructive.

Everyone present at this meeting seemed full of questions and subjects for discussions, therefore, making it very interesting.

SYRACUSE CHAPTER

The Syracuse chapter of the American Society for Steel Treating held its December meeting Friday evening, Dec. 8, at the Chamber of Commerce. The meeting was preceded by a dinner which was served at 6:15 p.m.

The speaker for this meeting was Franklin Shepherd who presented a very capable paper on "Carburizing." There were about 75 people present at this meeting and all enjoyed an interesting and instructive evening. Following Mr. Shepherd's paper a lively and profitable discussion was held.

TRI-CITY CHAPTER

The regular monthly meeting of the Tri-City chapter of the Society was held Dec. 14 at the Davenport Chamber of Commerce. The meeting was preceded by a get-together dinner served at 7 p. m. About 35 were in attendance at the dinner.

The meeting was called to order at 8 p. m. by the chairman. The chairman reminded the membership that the Membership and Attendance contest among the various chapters was now going on and urged the

members to bring in new members and to attend meetings regularly. The chairman then turned the meeting to Mr. A. H. Putman for a round table discussion on carburizing. Thirty minutes was allotted for this discussion.

The chairman then introduced the speaker of the evening, S. C. Spalding, metallurgist, with the Halcomb Steel Company, Syracuse, New York, who presented a paper entitled "WHY DID IT BREAK." Mr. Spalding gave a talk which covered the results of many years of experience in determining how and why steel parts fail in service. Mr. Spalding emphasized the necessity of co-operation between the steelmaker, the designer, the metallurgist, the fabricator, and the hardener. He showed the ill effects of sharp corners and sharp changes in sections. He pointed out the failure which might occur through too rapid or non-uniform heating and irregular cooling in the hardening operations. He pointed out the necessity of heating slowly, uniformly, and thoroughly. Mr. Spalding also pointed out characteristic defects which might occur in the grinding operation which frequently follows hardening. He gave a method for determining whether or not the failure was caused by the grinding.

In the discussion which followed the paper, questions were asked as to whether some of the characteristic defects might not be due to the cooling rather than to improper heating. Mr. Spalding replied that the failure might have been due to either cause.

A rising vote of thanks was tendered to Mr. Spalding for his excellent paper.

The chairman announced that the next meeting would be held on Thursday, Jan. 18, 1923 and that Mr. J. P. Gill, metallurgist with the Vanadium-Alloys Steel Company would speak on the subject of high-speed steel.

The meeting adjourned at 10:15.

TORONTO CHAPTER

Renewed activity and outstanding interest marks the rapid advancement of the condition of the Toronto Chapter.

A recent re-organization has been effected, whereby Colin C. Rous has been elected to the chairmanship of the chapter, while H. E. G. Watson, Supt. of the Industrial Division of the Consolidated Gas Company has accepted the position of Secretary-Treasurer.

An executive committee of five prominent men in the city have accepted their appointments, and are holding meetings regularly in order to arrange and divide the program that will meet with the greatest amount of interest from the membership.

Marcus A. Grossmann, metallurgist of the Atlas Steel Corp., Dunkirk, N. Y. addressed the first meeting of their chapter on Nov. 24, in the offices of the Consolidated Gas Company.

Mr. Grossmann used as his subject, an illustrated lecture on alloy steels, and presented the subject in such an interesting and entertaining manner that all of the large number present were very favorably impressed with the speaker and obtained an excellent insight to the manufacture of alloy steels.

The chapter is looking forward to a very interesting and enlightening series of meetings during the coming winter, and there is no doubt that

the hopes of the newly-elected officers will be fully realized in having a successful year.

WASHINGTON CHAPTER

The Washington Chapter held its November meeting on the night of Nov. 24, at which time W. R. Shimer, metallurgist of the Bethlehem Steel Company gave a very interesting paper on the manufacture of steel. Mr. Shimer's paper was illustrated with stereoptican slides and traced the manufacture of steel from the ore bed to the finished product.

Following Mr. Shimer's paper, J. E. Howard, engineer-physicist of the Bureau of Safety of the Interstate Commerce Commission remarked that experience in the behavior of steel has shown at times a close approach to the limit of ultimate endurance of the metal. He stated that steel rails in railway service afford illustrations of this kind, demanding, if obtainable, an advance in the ability of the rails to meet the conditions which are imposed upon them. He pointed out that it was a controversial point between steel makers and railroad engineers as to whether the limits of the endurance of steel are really being reached, or whether the grades of steel put out by the steel mills are responsible for the failure of the rails to endure track and service conditions.

Mr. Shimer's paper raised many points for discussion and proved to be an interesting subject and was enjoyed by all those that were in attendance.

The December meeting of the chapter was held Wednesday, Dec. 20, in the auditorium of the New Interior Department Building, corner Eighteenth and F Sts., N. W., at which time B. F. Shepard, Asst. Supt. of heat treating, Ingersoll-Rand Co., Phillipsburg, N. J., presented a verp capable paper entitled "Carburizing." The subject of carburizing for case-hardening has long been a topic of intense interest to steel treaters, inasmuch as there are so many factors which enter into the production of a satisfactory and serviceable finished product.

Mr. Shepard has had wide experience in this work at the plant of the Ingersoll-Rand Co., having specialized in the field of carburizing and case-hardening, and he presented some very interesting and pertinent facts pertaining to the proper carburizing of steel. Mr. Shepard's paper brought out considerable interesting and very instructive discussions, which proved to be of interest and benefit to all.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A repesents Associate Member; S represents Sustaining Member; J represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

NEW MEMBERS

ANDERSON, E. E., (M-11), 4724 Hastings Street, Detroit, Michigan.
ANDERSON, H. E., (M-12), 917 11th Street, Rockford, Ill.
ANDERSON, K. G., (M-11), J. L. Clark Manufacturing Company, Rockford, Illinois.
ARMSTRONG, G. J., (M-12), Columbus McKinnon Chain Co., Tonawanda, N. Y.
AYLING, JAS., (A-6), Case Hardening Service Co, Cleveland, Ohio.
BABCOCK & WILCOX CO., (S-11), 85 Liberty Street, New York City.
BEAUVAIS, P. J., (M-12), 5649 Eldred Street, Detroit, Michigan.
BERRY, T. J., (M-11), 2904 Mishawaka Avenue, South Bend, Ind.
BETHLEHEM STEEL CO., (S-12), Sales Department, Bethlehem, Pa.
BOWMAN, H. V., (M-12), 3640 34th Ave. S., Minneapolis, Minn.
BOYD, CHAS. F, (M-12), Nordyke & Marmon Co, Indianapolis, Ind.
BRADLEY, W. M., (M-12), 1404 North 62nd St., Philadelphia, Pa.
BRAY, H. M., (A-12), Colonial Steel Co, Pittsburgh, Pa.
BRICKNER, CAPT. L. M., (M-12), Aberdeen Proving Grounds, Aberdeen, Md.
BUCHER, F., (M-11), 711 Park Avenue, Dunkirk, N. Y.
CALEF, J. F., (M-11), 1001 W. Van Buren St., Chicago, Ill.
CANDEE, H. M., (M-12, 17 Wood St., Union City, Conn.
CARBAUGH, PHILIP, (M-12), 849 N. Court St., Rockford, Ill.
CHAWNER, G. F., (M-12), 605 Wethersfield Ave., Hartford, Conn.
COUNSINS, H. G., (M-12), 5299 Ivanhoe Ave, Detroit, Mich.
CRAN, JAMES, (M-12), 30 Glenwood Road, Albany, N. Y.
DAVIS, W. E., (M-12), 2462 Grand Blvd. W., Detroit, Mich.
DERR, A. G., (Jr-12), 1734 N. 15th St., Philadelphia, Pa.
DEUTSCHE, WM., (A-12), 519 Masonic Temple, Minneapolis, Minn.
DICKENS, A., (M-12), 5146 E. St. Clair St., Indianapolis, Ind.
DOWNS, F. R., (M-11), New Britain Machine Co., New Britain, Conn.
DREW, E. G., (M-11), Y. M. C. A., Moline, Ill
EADS, G., (M-12), 8050 Sprague Ave., Detroit, Mich.
EMMERT, R. J., (M-11), Remy Electric Co., Anderson, Ind.
FIRTH & SONS, LTD., THOS., (Sub-12), Publicity Dept. Norfolk Wks., Sheffield.
GODDARD, A. N., (M-11), 4727 Hastings St, Detroit, Mich.
GOGGINS, T. L., (M-11), 157 Clinton St., Schenectady, N. Y.
GREEN, M., (M-12), King Sewing Machine Co, Buffalo, N. Y.
GROFF, R., (S-12), S. S. Fretz, Jr., & Co., 23rd and Sedgley Ave., Philadelphia, Pa.
GUSTAFSON, C. A., (M-11), 23rd and University S. E., Minneapolis, Minn.
HAAG, W. B., (Jr-11), Montgomery Co., Philadelphia, Pa.
HARDING, W. S., (M-12), 311 Gerling St., Schenectady, N. Y.
HAUVER, A. N., (M-12), 6 Ashland St., Everett, Mass.
HAWKRIDGE, C. F., (A-11), 313 Congress St., Boston, Mass.
HEDGES, E. P., (A-11), 827 Elmwood Ave., Evanston, Ill.
HEISE, A. R., (M-12), New Departure Mfg. Co., Bristol, Conn.
HELRIGEL, F. H., (M-12), Motor Products Corporation, Detroit, Mich.
HOCKER, JOHN, (M-11), 522 Ave. H, Bethlehem, Pa.
HOWELL, WM. L., (M-12), Box 176, Midland, Pa.
JAMISON, J. F., (Jr-12), 204 Broad St., Philadelphia, Pa.
JOHNSON, A. R., (M-11), 1720 8th St., Rockford, Ill.
JOHNSTON, G. D., (M-12), 523 Hight St., Easton, Pa.
JOLLY, J. J., (M-12), 127 S. Salford St., Philadelphia, Pa.
JOSEPH, T. L., (M-11), U. S. Bureau of Mines, University of Minn., Minneapolis.
KASEY, JOHN (M-11), New Departure Mfg. Co., Bristol, Conn.
KENT, FRANK E., (M-12), 101 N. Virginia Ave., Atlantic City, N. J.
KELLEY, F., JR., (S-12), Peerless Belt Lacing Machine Co., Philadelphia.
KERR, JAMES F., (M-12), 69 Bristol St., Springfield, Mass.
KEWLEY, WM. C., (A-12), 506 Perry-Payne Bldg., Cleveland, Ohio.

KIRKPATRICK, T. L., (A-11), Wheelock, Lovejoy & Co., Cambridge, Mass.
LUTTS, F. C., (M-10), 3657 Vandyke Ave., Detroit, Mich.
MALONY, R. A., Jr., (Jr-12), 838 E. Price St., Germantown, Pa.
MANIER, R. L., (A-12), 205 Lillian St., Syracuse, N. Y.
MARSHALL, S. J., (A-12), Endicott Forging & Mfg. Co., Endicotte, N. Y.
MARTIN, F. P., (M-9), 530 Josephine St., Detroit, Mich.
MATHEWS, S. B., (Jr-11), 833 Wynnewood Road, Philadelphia, Pa.
McCLUNG, H. F., (M-10), 12853 Terry Blvd., Strathmoor, Detroit, Mich.
MERRICK, A. W., (M-11), 111 1st St., Scotia, N. Y.
MILLER, R. W., (M-12), 409 Wilbraham Rd., Springfield, Mass.
MOTT, H. S., (A-12), 216 W. Borden Ave., Syracuse, N. Y.
NELSON, W. E., (A-12), Firth Sterling Steel Co., Los Angeles, Cal.
NIEDRINGHAUS, G. H., (S-12), National Enameling & Stamping Co., Granite City, Mo.
O'BRIEN, T. S., (M-11), 17 Bedford Rd., Schenectady, N. Y.
ORAM, R., (A-11), 69 Carroll St., Buffalo, N. Y.
PARKER, S. W., (A-12), 127 Sidney St., Cambridge, Mass.
PARSONS, L. G., (M-12), 80 South St., Bristol, Conn.
PATRICK, J., (M-12), R. F. D. No. 1, Redford, Mich.
PERFECTION TOOL HARDENING CO., (S-11), 1229 S. State St., Chicago, Ill.
PFEIL, WM., (M-11), 813 South Bend Avenue, South Bend, Indiana.
PRETZ, C., (M-12), Studebaker Corporation, South Bend, Ind.
RAMSAY, GEO., (M-12), 707 Nott St., Schenectady, N. Y.
RAUCH, A. E., (M-11), Cutler Hammer Mfg. Co., Milwaukee, Wis.
REASONER, C. M., (M-10), 303 Walnut St. S. E., Minneapolis, Minn.
REITER, I. S., (Jr-11), 521 N. Ave. E, Bethlehem, Pa.
RICH, J., (Jr-12), 5129 Harlan St., Philadelphia, Pa.
ROFF, E. L., (M-12), 123 S. 11th St., Newark, N. J.
ROGLIN, E. C., (M-12), 10011 Parkgate Ave., Cleveland, Ohio.
SCHOEBERLEIN, GEO. A., (M-12), 906 Kirkpatrick St., Syracuse, N. Y.
SHELBY, J. B., (S-12), Driver-Harris Company, Harrison, N. J.
SHEPARD, G. V., (M-12), 757 Broad Street, Meriden, Conn.
SIGGELKO, W., (M-11), 1314 Logan Ave. N., Minneapolis, Minn.
SNYDER, P. M., (M-12), 1811 E. Main St., Massillon, Ohio.
STOKES, T. F., (A-11), 2 Foster St., Brookline, Mass.
TAPPER, G. W., (A-12), 413 Seitz Bldg., Syracuse, N. Y.
THOMAS, C. P., (M-9), 1107 Lee Street, Lansing, Mich.
THORP, F. Q., (A-12), 1131 Guardian Bldg., Cleveland, Ohio.
TRUEG, CHAS., (A-12), Pittsburgh Instrument & Mach. Co., Pittsburgh, Pa.
UNIVERSITY OF MINNESOTA (M-10), Minneapolis, Minn.
VOSS, T. H., (A-12), 4721 Pabst Ave., Milwaukee, Wis.
WESLEY STEEL TREATING COMPANY, (S-12), 651 S. Pierce St., Milwaukee, Wis.
WILLETT, G. H., (S-12), Standard Fuel Engr. Co., Detroit, Mich.
WIRZ, A. H., (S-12), A. H. Wirz, Inc., Chester, Pa.
WYMAN, L. L., (M-12), 713 7th Ave., Minneapolis, Minn.
ZABEL, GEO. W., (M-12), Fairbanks, Morse & Co., Beloit, Wis.

CHANGES OF ADDRESS

BACH, A. D., Jr., from Atlas Steel Corporation, Hanna Bldg., to Atlas Steel Corporation, 725 St. Clair Ave., Cleveland, Ohio.
BERMAN, I., from 72 Farmington Ave., to 133 Boulevard, Hartford, Conn.
CARTER, H. G., from Prospect St., Orange, to 65 Harding St., W. Newton, Mass.
CHERRY, R. M., from Nott St., Schenectady, to 103 N. 50th St., Philadelphia.
COBLE, C. C., from Charles St. to 522 Longwood St., Rockford, Ill.
CROSBY, V. A., from Lincoln St. to 630 N. Walnut, South Bend, Ind.
CUENOT, P. A., from American Locomotive Works, Schenectady, to 2018 N. 3rd St., Harrisburg, Pa.
CULLEN, J. F., from Delevan Ave., Buffalo, to Union Electric Steel Co., Carnegie, Pa.
DORSAM, A. J., from Water St. to 1813 E. Hagert St., Philadelphia, Pa.
FALES, H. G., from Highland St., W. Newton, Mass., to Emmons Apts., Huntington, W. Va.
HARDER, O. E., from University Ave. to 208 Cecil St., Minneapolis, Minn.

HICKOX, W., from 10th Ave., Rockford, Ill., to 743 32nd St., Milwaukee, Wis.
HILLMAN, S., from 6th St. to 1219 10th St., Rockford, Ill.
HODGEON, H., from Dale Ave., Muskegon, to 15141 S. Marshfield Ave., Harvey, Ill.
HOGAN, E. J., from Hughes Tool Co. to 2609 N. Main St., Houston, Tex.
HORN, D. H., from Vanadium Bldg. to Mesta Machine Co., Pittsburgh, Pa.
HUGHES, J. O., from Michigan Ave. to 114 E. Broadway, South Bend, Ind.
ILLNER, G., from Illinois St. to 3050 Lenox, Detroit, Mich.
IRONS, W. V., from Univ. of Buffalo to 3425 Main St. Buffalo, N. Y.
JACKMAN, A., from Mo. Athletic Assn., to 831 Westgate Ave., St. Louis, Mo.
JOHNSTON, W. E., from Quincy St. to 2624 Lyndale Ave., Minneapolis, Minn.
KERSLAKE, R. E., from Stop 7 to 19551 Euclid Ave., Euclid, Ohio.
KNAPTON, F. N., from Wilbraham Rd. to 48 Dearborn St., Springfield, Mass.
KOEPPEN, E. W., from Adams St., Chicago, to 651 11th St., Milwaukee, Wis.
LANNING, I. A., from New Departure Mfg. Co., Bristol, to 76 Franklin St., Meriden, Conn.
LARAWAY, W. P., from Sargent St. to 39 Maplewood Ave., Hartford, Conn.
LINCOLN, T. J., from Spring St., Meriden, to 59 Judd St., Bristol, Conn.
LUEBKE, O., from Clinton St. to 924 Pennoyer St., Grand Haven, Mich.
MAHONEY, J. D., from Hamilton St. to 11 Iowa St., Dorchester, Mass.
MARLOWE, J. S., from 7 Mayflower Apts. to Box 1173, Indianapolis, Ind.
MAYER, R. W., from Reliance Bank Bldg., Cleveland, to Brown Instrument Co., Ford Bldg., Detroit, Mich.
MENGES, L. A., from Lafayette Motors Co., Indianapolis, to Lafayette Motors Co., Milwaukee, Wis.
MIRZYEUSKI, J. A., from 23rd Ave., Milwaukee, to 4800 Beloit Rd., West Allis, Wis.
PIERCE, P., from Ruckle St. to 3821 E. Washington, Indianapolis, Ind.
REMINGER, G. E., from Ludlum Steel Co. to 3128 E. 99th St., Cleveland, O.
RICHARDSON, S. A., fromMadison and Robey Sts., Chicago, to University of Minnesota, Minneapolis, Minn.
RIEGER, W. H., from Donaldson Rd., Buffalo, to Union Elec. Steel Co., Carnegie, Pa.
ROBINSON, J. W., from C. H. Wills & Co., Marysville, to 309 W. Grand Blvd., Detroit, Mich.
SARGENT, J. F., from Ward St. to 131 Church St., Wallingford, Conn.
SCHMID, M. H., from 11th St. to 1303 Market Ave., Canton, Ohio.
SIKOROVSKY, F. G., from Springfield Ave., Chicago, to 2103 S. 62nd Court, Berwyn, Ill.
SIMMONS, C. F., from Latrobe Elec. Steel Co. to 25 B-Way, Room 2242, New York City.
STARKEY, F. H., from Whitney Mfg. Co. to 94 Warrenton Ave., Hartford, Conn.
STARY, L. G., Jr., from W. 90th St. to 3345 Fulton, Cleveland, O.
STRANAHAN, L., from Cleve. City Forge & Iron Co. to 1131 E. 145th St., Cleveland, Ohio.
SWART, C. A., from University Ave. to 142 Mildred Ave., Syracuse, N. Y.
TAYLOR, L. E., from 6th St. to 1131 Fairview Ave., Rockford, Ill.
TRICK, W. A., from Stanley St. to 680 W. Main St., New Britain, Conn.
TURNQUIST, E., from Miami St., Wabash, to 332 W. 9th St., Anderson, Ind.
WEBER, J. E., from P. O. Box 899 to 709 6th Ave., New York City.
WOODWARD, A. F., from Kinsman Rd., Cleveland, to 30 Burtt St., Lowell, Mass.

TRANSACTIONS

of the

American Society for Steel Treating

Vol. III Cleveland, February, 1923 No. 5

STEEL OUTLOOK GOOD

DURING the past year, the iron and steel production of the country, which is the unfailing barometer of general industrial activity, has displayed an impressive exhibition of recovery and expansion. This improvement which has taken place since the middle of 1921 has been almost continuous, and its extent as indicated by the fact that the tonnage of pig iron during the last month of 1922, was more than two and one half times as great as it was in July, 1921.

At the present time there is every indication that this prevailing activity of the iron and steel industry will continue during the coming year. The general recovery of business which is now in progress was in a large measure started and kept up by the building construction boom during the past year and one half. Also, the renewed purchasing activity of the railroads and the unexpected extensive activity of the automobile industry has aided this progress to no small degree.

Nearly 50 per cent of the iron and steel of the country is consumed by the building construction business, the automotive industry and the railroads, and if the tonnage of iron and steel used in the oil, gas and water installations be added to this list, we would find that these industries consume more than 60 per cent of the total tonnage of finished steel produced in the United States. Statistics show that for every 100 tons of steel which is produced, about 25 per cent is used by the railroads, about 15 per cent for oil, gas and water pipes and tanks, about 13 per cent for building construction, and 9 per cent for the automotive industry.

These facts warrant the prediction that the iron and steel industry will undoubtedly enjoy an active and prosperous year. It is patent that there is still a shortage of building construction, and of railroad equipment and moreover it seems certain that during the next year there will be a very great volume of automobiles produced and sold.

The iron and steel industry at the present time is illustrating one of the economic principles of periods of business recovery, which has frequently been observed in previous years. This results from the condition that when business begins to expand after a period of depression, those firms which first return to a profit making basis are those manufacturing products which are sold directly to the consumer. As this rule operates, firms producing and selling direct, usually draw upon their storage surpluses and manufacture their products from these reserves. It is not until some time later that it is necessary for them to buy new

raw materials to carry on their production. This has been the condition for the past year and one half with the result that the present year promises to be a year of very much increased activity for the steel business in replenishing the raw material supply for further manufacture into finished products.

COMMERCIAL TRAINING OF ENGINEERS ESSENTIAL

THAT engineering college graduates are handicapped without a supplementary commercial training is the basis of research investigations recently completed by Dr. W. F. Rittman and W. F. Reilly, of Carnegie Institute of Technology, Pittsburgh. In the *Carnegie Technical Journal*, a quarterly publication of the alumni and students of Carnegie Tech, Messrs. Rittman and Reilly present substantial proof of the need of commercial training in technological college courses.

With the co-operation of the alumni office, a study of the present occupations of Carnegie Tech graduates was made. Of the graduates from 1908 to 1921, the investigations showed that approximately 67 per cent of the total engineering graduates are now engaged in commercial or managerial work. This majority becomes significant in consideration of the fact that "engineering" graduates include a wide range of highly technical fields such as mechanical, electrical, civil, chemical, metallurgical, mining, sanitary, and science.

An interesting tabulation in the report shows the following percentages of engineering graduates in all departments who are now in commercial or managerial capacities: mechanical engineering, 65 per cent; electrical engineering, 60 per cent; civil engineering, 73 per cent; chemical engineering, 59 per cent; commercial engineering, 91 per cent; metallurgical and mining engineering, 67 per cent; sanitary engineering, 60 per cent; science, 77 per cent.

One of the two most important generalizations cited by the authors in their report is that "the great majority of graduates use their technical education as a means of getting into commercial or managerial work. It is believed that a similar study of the activities of the graduates of other technical institutions corresponding to Carnegie Institute of Technology would show this same order of classification, which seems to be natural and in conformity with the trend of the times."

GOING UP

THERE are many important factors necessary to success. These necessary factors will vary according to the line of work one is in, but there are certain fundamental principles of success that are common to all lines of industry.

Probably first and foremost in the list one would place strength of character. Character is a tangible asset and while it is possessed by nearly everyone to a certain degree it may be in either a strong, medium or weak condition. Character must have great tensile strength because it will be subject on many occasions to serious strains, and

consequently must be able to withstand the depreciable effects of fatigue.

Next on the list one would place genuine fondness of work and a particular fondness for the work one is in. One too frequently is accustomed to feel the truth of the old saying "everything is beautiful where I am not", thinking that other lines of work have more attractiveness than their own, but going up to the top is always attained by those individuals who are in a work to which they are best adapted and to which they are of course able to give their best endeavors.

Success entails the willingness to finish the work of others as well as a bad memory for quitting time. One should always be conscious and have a due sense of appreciation of the other fellow's efforts and a constant striving to increase your own efficiency as well as outdistance the accomplishments of others in the organization.

A certain steel given the proper heat treatment will possess real ability to perform the work for which it is intended and so it is with the individual who wishes to ascend to the top of the ladder, he must have real ability for the work in hand as well as good judgment and common sense. Good judgment and common sense as well as real ability, is a respectable order but they are possessed by many members of our society who have failed to have sufficient confidence in themselves to let their light shine outside of the cover of the bushel basket.

Intimately joined with the above formula for reaching the top, is that the individual should have a never failing ambition. Ambition after all is one of the prime requisites for rising above the ordinary individual with whom we all start and one's rise will be in direct proportion as one cultivates and continues ambition—the stepping stone to success.

STEPS FORWARD

TWO valuable contributions in the form of symposia are added to to our fund of information. These symposia were held at the 1922 annual convention of the society in Detroit. Under the chairmanship of one profoundly interested in the hardness testing of metals, the hardness testing symposium has made commendable strides toward the solution of the problem of, first, determining what property of a metal the term hardness specifies and second, how this property can be accurately measured, both scientifically and practically.

Of the various methods of measuring hardness, no one of them seems to be adequate in determining the hardness of the many types of materials found in commercial work. The committee in charge of this work is carrying forward this capable undertaking and we may well expect to hear favorable progress reports from time to time.

The second symposium had to do with the proper and adequate training of students in our many educational institutions. Many interesting points relative to revamping present curriculums in our technical schools were brought out. The gist of this entire symposium was not how to teach but what to teach. Many valuable contributions to this session were made and it is more than likely that this work will assist numerous educators in rearranging their curriculums to better meet the demands of the engineering profession in the future.

SYMPOSIUM ON HARDNESS TESTING HELD AT THE FOURTH ANNUAL CONVENTION OF THE SOCIETY, DETROIT, OCTOBER, 1922

THIS meeting under the chairmanship of Major A. E. Bellis, was called to order at 11 a. m. Friday, Oct. 6, 1922. In opening Major Bellis presented briefly the objects of the symposium and commented upon the results of recent investigations along this line. Following these introductory remarks the first speaker presented his paper as follows:

SIGNIFICANCE OF HARDNESS TESTS

By H. P. Hollnagel, Ph. D.

Introduction

THE term *hardness* is used to mean so many different things, and has received so much attention in recent years, that it seems desirable to gather some of the facts in a more concrete form.

The present paper, therefore, calls attention to a diversity of viewpoints and to those physical properties which are always intermingled with hardness discussions.

Definitions of Hardness and Allied Properties

A physicist tests a piece of steel for its hardness. In so doing, he skilfully places and adjusts a microscope so that he may properly observe the specimens, and then causes a very fine scratch to be made with the proper implement under slight pressure (using the crystallographer's hardness scale wherewith to judge it). This under reproducible conditions. He then carefully examines the width, depth and general physical character of the scratch as the microscope is moved from crystal to crystal, studies the wonderful realm thus opened to him, and from this survey determines the hardness.

The engineer scratches the same specimen with a file or some tool, whose angle is definitely known, and under a pressure determinate or otherwise, applied in a similar manner. He arrives at a degree of hardness established by an elimination test as determined from a series of such tools drawn to certain degrees of hardness. Definite and reproducible conditions are established in making his determination and he is satisfied with the result of this interesting test. He compares the value thus obtained with that of the physicist and finds it very different. Why? Because one deals with the exceedingly minute, while the other deals with the average; one is a microscopist, the other a macroscopist. How can they hope to agree? Impossible without some correlation!

Concept

The concept of hardness originates from a sense of resistance offered by material to the action of an approximately static force. As to its specific

A paper presented before the Detroit convention Symposium on Hardness Testing, October 6, 1922. The author, Dr. H. P. Hollnagel, is associated with the department of physics of the Thomson Research Laboratory of the General Electric Co., West Lynn, Mass.

The Symposium on Hardness Testing was under the direction of the Hardness Testing Committee of the National Research Council of which committee Major A. E. Bellis, is chairman.

character, there is diversity of opinion; the engineer believes it fundamentally important, while the physicist does not recognize it as one of the more essential properties of matter.

There seem to be two general classes of hardness—superficial hardness, otherwise referred to as resistance to abrasion, and penetration hardness, otherwise referred to as deformation hardness. Both of these are spoken of as resistance to penetration or deformation of shape. In practice, one seldom occurs without the other; whether the cutting of a metal, or its wear and tear upon another under pressure is considered.

A so-called academic definition of this engineering property should cover both classes and might be stated as follows: Hardness is the cohesive resistance of the molecular-aggregate structure of a material to any deformation of form. For the engineer, this is utterly worthless. He neither deals with limited structures uniformly loaded, nor with large molecular aggregates in which there are highly localized strains, but rather with the combination of the two. Seldom is the stress so distributed, that either of the two may be considered applicable to or independent of the other.

Moreover, mechanical limitations such as dimensions, manner of application of the stress, together with its magnitude and duration, are factors of a very indefinite character. The result of such indeterminateness is a multiplicity of definitions, depending largely upon the personal aims of particular individuals.

Among these definitions, may be mentioned hardness, as determined by scratch, wear, rebound, crushing, bending, penetration and deformation and impact.

Scratch Hardness

Perhaps the oldest of these is scratch hardness, which characterizes the property or quality whereby one material abrades another, the scratched material being the less hard. For the minerologist the Moh scale, Diamond 10, Sapphire 9—Gypsum 2, Talc 1 is standard, the high numbers being harder than those beneath them. Referred to this basis, the engineer utilizes a file test, ascribing a hardness of 6, 5 or 7 to such materials as are scratched by a file of a certain type. Copper and ductile wrought iron are thus rated as 3 and 4.5 respectively.

Wear

Hardness is also defined as the resistance to wear as determined by the amount of material removed measured in thousandths of millimeters; the degree of hardness is thus fixed if worn off under fixed load in proportionate times. Very often this hardness has been confused with and interpreted as that of scratch, but as will be seen, this is not permissible.

Rebound

In the ball bearing industry, the height to which the specimens rebound, when dropped upon a fixed plate properly hardened, has been taken as a measure of hardness. This is not truly a hardness test, but rather an indication of the resilience of the material. It measures the energy stored in the compression wave of both the material being tested, and that upon which rebound takes place. If you like, it measures the coefficient of restitution of

this material with respect to the plate. This may in certain types of test cause the yield point to be exceeded, in which case true resilience is not obtained, but rather that of deformed material.

Crushing

Still another test makes use of the crushing of the specimens themselves. In this case, the fracture is examined microscopically and the hardness judged therefrom. Presumably, the degree of packing determines the hardness characteristics in this case.

Bending

For wires and small sectional specimens, the resistance offered to bending is very often taken as a measurement of hardness. In such cases, it is customary to determine the number of reversals, to which a given specimen may be subjected without rupture, by bending through definite angles. The lower the number, the harder the material.

Penetration

Resistance offered by material to penetration is more generally said to be the definition of hardness. It is preferable to use the term "penetration" rather than "deformation" as the latter should be reserved for another characteristic. In measurements of the type which require the surface to be penetrated, it is necessary that the proportionality limit of a portion of the material be exceeded as well as the yield point. Once the latter has taken place, further deformation of material meets with resistance which is more than proportionately greater. This resistance is what I have elected to call "deformation hardness." It is the resistance to deformation beyond the proportionality limit and yield point of the material, and is the type of hardness usually measured by any of the indentation devices.

Penetration, just through a surface, will determine superficial hardness; through a definite thickness of material thereby causing permanent set, a hardness dependent upon the heat treatment to that depth; to a depth greater than this, a value of greater magnitude depending entirely upon the depth of such indentation. In practice, these hardnesses are all dependent upon the deformed state; that is, the material ahead of a penetration device is packed more and more once the proportionality limit is exceeded and becomes harder to the point of rupture.

Impact

For the cases thus far discussed, the outstanding physical treatment common to all is deformation of form. To be sure, deformation is not accomplished in exactly the same manner, and in most cases, is attended by permanent set. There is the exception—the elastic resilience of balls, in which case permanent set rarely occurs. If the contrary is the case, the test no longer is a measure of resilience alone.

Almost any impact hardness test is either of the resilient or semiresilient type. In a hardness test in the ordinary sense of the term, a permanent deformation is produced. In such cases, hardness is at times defined as the energy expended per unit volume of the indentation caused by impact. This is an unfortunate concept, as resistance is force, and should not be misconstrued with energy which is its space inegral. As has been previously alluded to, impact is usually accompanied by a rebound which depends on the rate

at which the compression wave travels into the specimen and the impacting medium. If you choose, rebound is a function of the duration of impact.

Time

In general, no restrictions are placed on the time of application of the stresses. One might conclude from this that time was of no consequence in hardness testing. A simple consideration of the time required to accelerate masses to a given velocity, however, calls to mind the fact that it is very important even though such masses be of molecular magnitude. We are concerned usually with such as are caused to slip upon like molecular masses, and from this viewpoint a force constantly applied for a considerable time should ultimately penetrate farther into a material of given hardness, other things being equal, than one characterized by the same momentum, but acting for an indefinitely short interval. The latter force might well surpass by a very great margin, the proportionality limit and yield point, and the material not show signs of rupture. In a few words, it requires time for slippage to occur. (Brittle materials are referred to later.)

It is evident that there is insufficient agreement among various definitions and those factors which determine their validity, and that more definite specifications are required.

Let us examine some of the reasons for failure of a few of these definitions and tests.

Discussion of Tests

Scratch Test

Can a scratch give a true value of hardness? It is questionable, for it depends

1. Upon the operator's personal equation
2. Pressure at which the tool is applied
3. Type and character of tool
4. Angle at which tool is ground, and at which it is applied to the work
5. Speed of application
6. The uniformity and character of material

Furthermore, diamond cuts diamond, broken glass cuts glass, depending entirely upon a molecular rearrangement of amorphous material on fracture, and the chemical constitution of specimens. The grain structure of diamond, which makes possible the cutting of a stone by its chips, probably is a molecular rearrangement at slip planes whereby this region becomes much harder. That is, its physical properties are much changed in a manner somewhat similar to the case of the modified virgin material within the earth about a geologic fault after the same has occurred.

Effect of Speed

As all of the determining characteristics of a scratch excepting the fifth are fairly self evident, it may not be out of place to cite experimental evidence in substantiation of the effect of speed.

A wrought iron disc rotating at a linear speed of 30 feet per second may readily be cut by a steel tool; when rotating at 100 feet per second, it readily cuts steel tools, and when rotating at 300 feet per second, it readily cuts quartz, which has a hardness number of 7 based on the Moh scale. That is to say, it is as hard as a steel file. Speed therefore is a very important factor and should be given due consideration in cutting operations.

Resistance To Wear

May one conclude from a scratch test that resistance to wear of a piece of steel shafting is predetermined? This is questionable; after the first few 1000 revolutions of the shaft, its surface is no longer in the original state, it is polished, and, though not measurable by any of the present methods, is harder than before. A polished metallic surface is considered to be an amorphous state of metal. Under polishing conditions, the metal becomes plastic and solidifies at a rate permitting of the formation of no new crystalline masses, rather any fractured crystals which may occur act as nuclei about which the metal is packed more closely than before. This means finer grain structure.

Under conditions of wear, in a bearing, these circumstances are approached and the shafting hardens on the surface as the wear progresses. This is generally referred to as the packing of fine grains among the larger, and where the load is the greatest, the packing with its resulting hardness is a maximum.

Analysis of Scratch

In itself a scratch is not a proper indication of hardness. It may be considered a measure of a surface property—Scratchivity—which is related to the skin hardness of a material. Examined closer, how may one consider a scratch produced?

A sharp instrument under normally, or otherwise applied pressure bears on a surface; before a scratch is begun, an indentation is produced locally, either gradually or suddenly, so that as the tool advances, the material ahead of it is compressed; the proportionality limit and yield point are exceeded and rupture caused. An aggregate of grains topples out, others are packed into slip planes; the further application of continued stress on material already distorted causes more compression and incipient cracks, rupture and more loose grains, and so the scratch progresses. Unquestionably, such cracks may be observed in the material just ahead of the tool. While all of this occurs in a very short interval of time, it has the elements of every deformation and rupture process; there being, however, no material above the surface along which the tool is traveling. Slipping takes place more readily in a direction in the neighborhood of 45 degrees with the horizontal which causes a lower degree of hardness on the average than the hardening effect alluded to above, that is the hardening caused by deformation. Therefore, when compared with indentation hardness, it will of necessity be low.

Hardness By Penetration

In studying hardness as measured by penetration, one is confronted with the unfortunate features of all penetration hardness methods, when attempting to characterize the physical properties of a material like manganese steel. By their use, one is not able to differentiate between the characteristics of manganese steel in its virgin, rolled or worn state. In fact, this is the crux of the whole situation. A material under compression changes in hardness, becomes more resistant to penetration as it increases up to the point of rupture of grain structure. Certain bronzes and duralumin act in exactly the same manner as manganese steel, showing different hardnesses after being rolled, hammered or worked. Therefore, it would seem that hardness depends as much upon the degree to which material has previously been deformed, as it does upon the rate at which this deformation has been carried out; in either case, these factors vary considerably with the material.

Can a penetration test lead to a true hardness? It would appear likely

if deformation were carried out to the yield point so rapidly that the resistant force at this point would be a true measure of the cohesive resistance. But can one uniformly load or stress a portion of material at a point just below rupture? Can one measure the true deformation at this point, having accomplished it in a proper time? Neither of these questions can be answered in the affirmative. Considering the time involved to stress a body to its yield point, which may be impracticable, the answer is not simple.

Rebound and Impact

Rebound or impact may only determine the degree of hardness when the proof resilience has actually been approached. This is a decided function of the time of application of the impulse stress during which the ultimate limit may well be exceeded in value and still no permanent deformation result (this time must be sufficiently small). Moreover, the same and different materials have different proof resiliences, depending largely upon what their previous history may have been. Therefore, different impulse times will result and only such determinations can have significance when materials have uniform distribution of mass and equal times of impulse.

Crushing and Bending

In any crushing or bending test, the resulting decision must be dependent upon the prehardening by the working of the materials as a consequence of the test itself. Still it is conceivable that for a thoroughly standardized product (of definite method of preparation, chemical constitution, dimensions and heat treatment) such tests could have a significance from which conclusions as to the preliminary hardness could be drawn. But again, the time of carrying out such test has a most disturbing influence.

Brittleness and Ductility

Occasionally, in discussions on hardness, the term "brittleness" occurs, and in deformation of a permanent character, the term "ductility" is also often referred to; one may say a substance is hard and brittle, or hard and ductile. If brittle, its point of rupture is reached by the application of a very slight load beyond the elastic limit. For a brittle material, rupture and yield point coincide, for the state of aggregation is one in which decidedly limited displacements may take place, before the molecules become permanently detached from their centers of attractions. Materials of this nature may be conceived as being "keyed"* to the limit, so that the slightest slippage will cause rupture; certain brittle materials may have a fine grain structure so closely packed that it is conceivable that a state of no slippage could occur. This would account for the almost instantaneous rupture of certain classes of materials. In such cases, the cohesive forces are directly measurable by the yield point. Again, some materials are apparently brittle and plastic and in such cases they are brittle because of their rupture under suddenly applied or highly localized stress; whereas a constant force applied over a considerable period causes more and more flow. (An example of this is sealing wax).

There are also certain materials which are said to be soft, like chalk, in which very little force is necessary to separate the grains, still we know that chalk makes an excellent polishing material for hard material like quartz. This material is hard and soft from the microscopic and macroscopic points of view, respectively.

Materials are ductile because of the displacement possible of the

*By "keyed" is meant, that, minute fractured crystalline aggregates have been forced into positions between slip planes which do not permit said planes to further glide upon one another.

molecular aggregate of which they are composed. The extent of this displacement is fixed by the proximity of neighboring grains or aggregates. The greater this freedom, the higher the ultimate limit, and the greater the fatigue limit. (This is not used in the ordinary sense, but rather in the sense of the return of a material to its original state, after having been extended beyond the proportionality limit.) When fatigue passes into yield, an amorphous condition of metal is formed, which carries the interfering grains, causing increased strength. As a result of this, ductility is possible. Slip takes place between grain layers on plastic metal which acts as a viscous medium for them to ride upon, ultimately becoming "keyed," somewhat like the slippage of a pack of playing cards rendered sticky by molasses containing fine sand. The individual cards slip one upon the other, and finally set. Hardening as a result of work is an identical phenomenon.

Plasticity And Tenacity

In the sense here used, plasticity is the ability of a body to flow under pressure. Tenacity is the resistance that a body offers to such flow.

Most materials become plastic under great pressure maintained for a sufficiently great time. On the amorphous metal theory, plasticity should aid in making a material more tenacious for the reason that the crystalline or grain structure is decidedly much more minute than previous to the plastic deformation. If you choose, the intermolecular lattices are then filled with interfering material, which renders the possibility of slipping more remote, as a result of which a material becomes more tenacious and harder.

General Conclusions

From what has been said, it is evident that hardness is a very complex characteristic, being explainable only in terms of interatomic phenomena. No better evidence of this fact can be introduced, it seems, than the viewpoint of two eminent Englishmen, one a pure scientist, the other an eminent engineer.

Prof. A. H. Tutton, a crystallographer, says that the hardness of solid substance may be defined as the resistance offered by a smooth surface of the substance to abrasion. It is measured by a substance just being abraded or scratched by contact with a sharp fragment of another material whose degree of hardness is precisely known in terms of a conventional scale. In this process of measurements, the cohesive force of the softer material (which force is closely allied to hardness) is overcome.

Crystalline substances show different degrees of hardness in various directions. Along a cleavage plane they are less hard than in a direction at right angles thereto. These planes which are parallel to each other, are densely populated with atoms. Between them, the space density of atoms is much less. Therefore, cohesion is a minimum in planes at right angles to the cleavage plane. Particles are more easily torn away along the cleavage plane by shearing in this direction.

High specific gravity is generally accompanied by great hardness. (Lead and gold are exceptions.)

In space lattices, this means the closer the atoms are together, the denser the substance. Therefore, great difficulty is met with in overcoming cohesion, according to the laws of attractive forces between gravitating particles.

According to Sir Robert Hadfield, hardness as ordinarily defined is

the resistance to penetration. In general, a greater resistance is offered by materials already deformed than that required to produce the first permanent deformation in the same undeformed material. That is to say, there is a natural hardness and a deformation hardness.

No single value may be assigned to hardness in the general sense. It can only be expressed by a stress strain curve.

Hardness can be measured only by the yield point stress. (Except in such materials as pitch.)

No satisfactory method of measuring deformation-hardness, that is, the hardness of materials already deformed, has been developed. Scratch tests permit of comparison of this more or less definite property, but do not offer the possibility of numerical comparison. Other methods of measuring hardness determine the resistance of material deformed to varying amounts in different parts; therefore, it cannot be expected that they can agree among themselves or give a numerical value of hardness which bears a fixed relation to any of the others.

Brittle materials are subject to few or none of these complications of deformation hardness, and are therefore measurable as has been previously indicated.

Discussion of Dr. Hollnagel's Paper

Chairman A. E. Bellis: We are greatly indebted to Dr. Hollnagel for presenting this paper. He has certainly brought out the fundamental views of hardness testing. There will be further discussion of methods of hardness testing, but I think now is the time to make rational suggestions about the way of looking at hardness. I wish those that have questions would not hesitate to bring them up now.

Mr. E. E. Thum: The paper we have just heard discusses many features of hardness and from the standpoint of the steel treater and engineer, it seems to me that a great many of the problems that Dr. Hollnagel states can be pushed to the background. As he points out, the physicists are interested in the hardness of the ultimate crystal. A metallurgist or heat treater can satisfy himself as to the scratch hardness of any particular material by studying its microscopic character. I believe there is a simple attachment which he can fix to the stage of his microscope wherewith to draw a sharp point quickly across the polished surface. The character of these scratches varies from crystal to crystal, and the properties of each would vary depending upon whether he looked at it from the north or northeast. It is necessary to study these things. A piece of metal, however, is an aggregate of extremely small particles. Theoretically, a study of these fine particles which change with each breath of wind, gives us further insight into the aggregate relation depending on the amount and size of the particles. Every time one heats and quenches a piece of metal he gets varying conditions. On the other hand every time one gives it a little cold work, opposite effects take place. Consequently, the hardness which he is studying, certainly is hardness of that aggregate and is bound to vary with the physical condition of the aggregate. Therefore, to the practical man it may seem entirely superfluous to attempt a definition of hardness which will not bring the ultimate and desired end. For that reason, a great many variations in the conception of hardness of

metal have arisen and the practical man may very well question the desirability of eliminating the various shop tests of his, which may be rough, it is true, but are extremely valuable and give him information which to him is good.

Dr. H. P. Hollnagel: The material presented in this paper has been gathered from the shop, by questioning those who have had occasion to use so-called hardness testers for various purposes. To be sure I have made use of the scratch to show that it is not a suitable test for hardness. I have taken it up for a very good reason, namely a scratch penetrates only to a depth dependent upon the pressure applied to the work. I think, however, that the engineer is not interested in the scratch test for all purposes. I have not tried to bring out any definite conclusions as to what the character of the ultimate hardness definition or test should be. Rather have I left that point to this symposium, and I am very glad to have points raised, the better to get in touch with your viewpoint for to some degree I might be inclined to be more theoretical than practical, but I can assure you that I have as many practical problems in my work as does the steel treater and some of them have had to deal with hardness.

Mr. Troendly: If we take a piece of steel, say 10 or 12 inches long, make it into the form of a test specimen, so that you have a means of test for a slow application of load, and apply the load, in practically ten seconds, you reach the full deformation that that load will produce. However, let that load be applied for one day and it will go about 1 per cent further. You reach your full deformation in 10 seconds, which is the period between the application of load and permanent set, and is the time element taken by the material in being stressed until the entire indentation has been formed. A slow and prolonged deformation will occur, however, for several hours. It is only a matter of how long it is permitted to progress. I think this sheds more or less light on the time element.

Dr. Hollnagel: The two points which have just been brought up are indicative of several which I have in mind. In all, the time of application of the stress is of paramount importance. There is no question, but that in the matter of impact, the time element is even more important than in the case of more gradual deformation. It might be safe to say that one can apply a force of the order of magnitude of one million pounds to a specimen that has an elastic limit in the neighborhood of 150,000 pounds per square inch, and not cause rupture, even though the ultimate limit of the material had been passed. We approximated this, that is, the specimen and impactor were in contact for a period approximating 1/10 of a thousandth of a second, and the force approximated the order of magnitude indicated. In impact machines or those of rebound type, time is a very important feature as well as in the indentation type of machine.

Mr. A. L. Davis: I have been greatly interested in all the various remarks, and particularly in bringing up different machines that differentiate between materials of different hardness. A practical steel man will know that different machines do not give the same result. In the old times, the file was the first thing that the steel man thought of and probably it has been used more by the steel treater than any other, if we consider a period of thirty years back. Now steel treaters

are well aware that the file of certain alloy steels consistently understates the hardness as found in actual wear. The Brinell and Shore tests have come in and given us a more convenient and accurate method of measuring hardness of steel and probably the file will be used less and less, although on some products, it is the easiest way to determine it. I believe that almost every man who is concerned with the practical testing of steel products feels the want of some better method than any now in hand, or possibly the development of tables correlating the results from various methods so that the results of one method could be immediately interpreted for the hardness character of material in terms of other tests. The subject is one of such inherent difficulty that no doubt exists, from papers that you have listened to, that it is going to take the efforts of many people to bring about a satisfactory solution for the practical man. I wish I had the data that could be submitted for correlation tables, but I think it is going to be necessary for us to start from the bottom and compile it in order to make accurate comparisons.

Chairman Bellis: We have a paper that has been submitted by Mr. German, metallurgist of the Henry Disston & Sons, Inc., Philadelphia, Pa. Mr. German is not here. I would like to continue the discussion after we have heard Mr. German's paper, that would bring up one or two subjects that have not been touched, I will ask Mr. J. J. Curran of the Henry Souther Engineering Company if he will read Mr. German's paper.

Mr. German's paper.

TESTING OF METALS FOR HARDNESS

By H. M. German

Definition of Hardness

HARDNESS is the ability to withstand abrasion or resist penetration. This is the definition that has been accepted for the term of general hardness. In recent years, there has been a tendency to provide more specific terms to steel, as follows:

Initial Hardness is the hardness obtained by quenching.

Temper Hardness is the hardness obtained by tempering initial hardness.

Case Hardness is the hardness of the surface of steel obtained by carburizing and quenching or caused by overheating in grinding.

Red Hardness is the property of a cutting tool to retain its hardness when operating at a red heat.

Types of Hardness Testing Machines:

For many years, hardness had no fixed measure but only a comparative value. For example, metals were compared with others of similar hardness in the same manner as minerals were compared to a standard: which ranges from talc, which is so soft it can be cut with a finger nail, to a diamond, which is the hardest known substance. This method was very unsatisfactory as the values could not be used in specifications (if they were used in the earlier days) for they had no

definite value. In order to provide a measure for hardness, many types of apparatus were designed. They may be roughly classified as follows:

1. Those measuring the resistance of metals by scratching or abrasion. Turner's sclerometer, which was designed to test the hardness of foundry irons, consisted of a balanced arm having a pointed diamond fixed on one end, so that the point of the diamond rested upon the polished surface of the piece to be tested. By moving a sliding set of weights along the arm, a pressure is reached when the diamond makes a standard scratch on a standard surface. The weight, in grams, on the diamond point is taken as a measure of hardness. Various modifications such as using a constant pressure on the beam and measuring the width or depth of scratch, and replacing the diamond with a hardened steel cube, are also used. This type requires a standard surface and can be used for testing all kinds of metals.

Scratching the surface of cutting tools, such as files, with a test piece of given hardness has been used for years as a commercial test to sort out those that are too soft and too brittle.

2. Those using the resistance of metals to cutting. Keep's drill test was developed to test the hardness of castings. In performing this test, a standard piece was placed under a drill of fixed size and grind and operating with a fixed speed and pressure. The number of revolutions of the drill to pierce the piece was taken as a measure of hardness. This type also requires a standard piece for testing but can only be applied to metals which are soft enough to drill.

Before passing on the next type, the file as a testing medium should not be overlooked. While only giving comparative values, the file test is the quickest, easiest performed, and, in many instances, the most reliable test for hardness and detection of decarburization that the heat treater has at his command. This applies particularly to testing hardened articles before tempering. In many plants hardened articles are file tested to determine the amout of tempering necessary. The file test does not require a standard piece for testing and the articles tested are not damaged.

3. Those using the resistance of metals to indentation. The earliest machines of this type consisted of a weight having a hardened steel knife-edge or holding an indenting tool of pyramidal or conical shape that was caused to drop, by gravity, on the piece to be tested. The depth or width of indentation was taken as a measure of hardness. These machines led to the development of the Brinell tester. This instrument presses a hardened steel ball of given size with a constant pressure on the piece to be tested. The standard size ball is 10 millimeters in diameter and the pressure, 500 kilograms for soft metals, such as lead or babbitt and 3000 kilograms for harder metals, such as iron and steel. The diameter of the depression, measured in millimeters by a microscope containing a calibrated scale, is taken as the measure of hardness. The practice at some plants is to use the diameter as the hardness measure, while at others, the Brinell hardness number, found by dividing the pressure in kilograms by the area of the depression in

square millimeters is preferred. The hardness number need not be calculated as it can be found by comparing with a chart furnished with the instrument. Various modifications of this type such as using weights instead of hydraulic pressure, and measuring the depth instead of diameter of impression are used but the principle remains the same. The Brinell method does not require a standard piece for testing, but it has its limitations as it is not applicable to brittle substances or those that cannot stand a permanent deformation, to thin sections, or to pieces where the depression hole would spoil the finish of the article.

The Rockwell test is a modification of the Brinell. It consists of pressing a hardened steel ball or a diamond cone, of 120 degrees angle, into the article to be tested and measuring the depth of impression with a dial micrometer. The size of impression is much smaller than in the Brinell test as the steel ball is only one-sixteenth of an inch in diameter and the maximum major load is only 150 kilograms when using the diamond cone and 100 kilograms when using the steel ball. Arrangement is also made to apply a smaller load of 60 kilograms, if desired, for soft metals. The method of applying the Rockwell test is different from the Brinell in that the total depth of depression from the surface is not measured. In making the Rockwell test, a minor load of 10 kilograms, regulated by a spring, is first applied to the ball or cone; the micrometer dial is then set at zero, or at a fixed point and then the major load is applied. Upon releasing the major load, the depth of impression caused by the major load only is indicated on the micrometer dial. By using a special reading glass, the diameter of depression of a steel ball can be read the same as in the Brinell test. The Rockwell test does not require a standard specimen, it does not spoil the finish of the article tested, except on very high polished work, and it can be used on much thinner sections than the Brinell (.010 inch for iron and .015 inch for brass), but it cannot be used for testing thin sections that are brittle or cannot stand a permanent deformation.

4. Those measuring the height of rebound of a weight when allowed to fall from a given height upon the article to be tested. The scleroscope invented by Shore, utilizes the above principle. It consists of a cylindrical weight one-fourth inch in diameter by three-fourths inch long having a diamond striking point, slightly spherical and blunt, about .020 inch in diameter. The weight is allowed to drop by gravity from a height of ten inches, through a vertical graduated glass tube on the article to be tested. The height of rebound is measured by noting the highest point of the weight against a graduated scale in back of the glass tube. Articles to be tested are placed upon a hardened steel anvil; the tube is clamped tight against the specimen, and the weight released by an operated spring. For testing large specimens the tube can be removed and attached to a swing arm or held in the hand. The scleroscope does not require a standard piece for testing; it does not spoil the finish of the article to be tested; it can be used on very thin sections and by holding in the hand or swing on very large sections.

Selection of Hardness Testing Machine

With the present and increasing competition among manufacturers, it

is absolutely essential that their products be turned out uniform and up to a given standard for hardness or temper. The product can be checked only with a standard by means of a testing machine that will give reliable values. File tests, are fairly satisfactory in certain cases, but for example, if a heat-treater was told to temper an article so as "to file readily" a term commonly used, it would not have a fixed value or even within close limits. Also the property of the article to "file readily" would be greatly influenced by the type of file used and the ability of the operator using it. Hardness values must be fixed not only in one plant, but they must be interchangeable so that manufacturers and customers can deal with each other in definite terms and thus draw up mutual specifications.

The principal hardness testing machines used are the Brinell, Rockwell, and scleroscope.

For testing articles within its limitations, the Brinell machine has, for years, been recognized as the standard. This machine is the most accurate and the most reliable that has been developed. It is always operated under a constant pressure and if care is taken to apply it gradually and to maintain it for a fixed period, consistent results will be obtained. Measuring the depression by means of a microscope containing a calibrated scale is accurate and possesses the advantage of having the operator observe the depression for roundness. The machine is exceptionally strong and rigid and will hold its adjustments for years.

The Rockwell machine is used to apply a modified Brinell test to articles that are too thin to be tested by the Brinell method. The manufacturers of the Rockwell machine definitely state that the machine will "test on a comparison basis." This should be remembered as the Rockwell machine does not read direct in terms of the standard Brinell. However, it is not difficult to test a number of pieces of a given steel having a hardness range from soft to hard on both the Rockwell and Brinell and plot a curve that will show a direct comparison of the readings. This curve will only apply to the class of material from which the readings were made. The physical properties of high carbon, low carbon, and alloy steels vary with the same hardness as measured by any hardness testing machine. Therefore, it is impossible to compare hardness results between two types of machines on one class of metal with a chart made with another; for example, comparing high carbon steel with manganese steel. Contrary to what has appeared in print recently, there is a definite relationship between hardness readings obtained by either indentation or rebound methods, and physical properties which are affected by hardness, such as: machining qualities, resistance to wear, etc. when comparing like articles under like conditions. It is folly to compare the machining qualities of steel versus aluminum by hardness tests, or the resistance to wear of manganese steel versus carbon steel, but there is a distinct relation between the machining qualities of a given type of steel having different hardness readings, and of aluminum of different hardness readings, and likewise a distinct relation between the resistance to wear of pieces of a given type of carbon steel having different readings, and pieces of a given type of manganese steel having different readings. Comparison readings can only be made with like articles. This applies to any type of hardnesss testing machine.

The scleroscope is used to test all types and sizes of metals by a comparison method. It has just been stated that comparison readings can only be made with like articles. There is an additional limitation placed upon

the scleroscope. Comparison readings can only be made with the scleroscope when testing like articles under like conditions. Some of the conditions that effect scleroscope readings are: size or thickness of the piece tested; flatness; condition of surface such as rough, ground, or polished; size and hardness of anvil under the piece to be tested; and whether the scleroscope tube is clamped tightly or held lightly against the piece to be tested. It is not possible to accurately compare the hardness of a thin piece of spring steel after it has been tempered with a like piece after it has been ground, or with a like piece that has been ground and polished. The effect of mechanical work in this instance causes the readings to become higher. It is possible, however, to compare readings of like pieces under like conditions. If this simple axiom was understood and followed, the following extract from a criticism on hardness testing would not have appeared recently in a prominent trade journal:

> "Whoever heard of hardness testing when wearing properties are what are really wanted? If the wearing properties are involved a test for resistance to wear, which has absolutely nothing to do with hardness, is the only information on this point that can possibly be obtained. Why blame *hardness tests* for the fact that there is no relation between 'hardness' and 'resistance to wear'? We might as well blame the Hudson River for flowing into New York Bay instead of San Francisco Bay.
>
> "The sentence, 'Hardness testing would tell us that steel gears are the best', is without sense in view of the well-known facts just mentioned. Since the scleroscope gives a higher reading on soft rubber than on hard steel, would anybody presume that gears of soft rubber would be 'the best'?"

There is a condition that will greatly effect the readings of a scleroscope and that is a decarburized surface, but why condemn the scleroscope for telling the truth? The steel-treater should know if the steel he is treating is decarburized and if the scleroscope indicates this condition, which it does, it is an aid in his work.

Conclusion

In conclusion it is hoped that this article will have shown:

1. That no one machine is adaptable for testing all kinds of work;
2. That the machines will give comparative results only when testing like articles under like conditions;
3. That reliable results can be obtained only by working under fixed conditions and observing necessary precautions;
4. That readings obtained from one machine can be changed to terms of the other machines.

Discussion of Mr. German's Paper

Chairman Bellis: Mr. Curran has done some interesting work on hardness testing problems, and I would like at this time to have Mr. Curran state his experience.

Mr. J. J. Curran: In connection with the Brinell test as described here, we had occasion recently to examine several different makes of Brinell balls to determine the effect the method of manufacture, etc. had on the readings that are obtained on a given piece. The samples we had were from four different manufacturers. One of them was a ball made especially for Brinell hardness tests—a carbon steel ball of

foreign manufacture and we wanted to determine definitely its suitability for the Brinell test. For comparison, we selected some special balls of chrome tungsten steel made by the Hoover Steel Ball Co. and two makes of chrome carbon balls made by two different manufacturers. We happened to have the latter three in use in our own laboratory. We had a very few of the carbon steel balls that started the tests, and we had very little idea at the start just how we were going at it, but we proceeded first to examine all types of balls, as we would have, were they intended for ball bearings. While that examination may not have much bearing on the use of a ball for the Brinell test, we decided to obtain this record for any information or service it might give later. It was interesting to notice that with respect to one very important feature in the life of a ball bearing, i. e., surface, finish or polish, the ball which ultimately showed up best for the Brinell test had the poorest surface. It shows that some of the standards that apply to bearing service do not apply to this test. The usual surface examination and measurements were made to determine sphericity and absence of flat spots, also scleroscopic tests were made under as near standard conditions as we could get. The foreign carbon steel ball was the hardest of all. We also ran crushing tests, that is, three ball tests, and the results were extremely variable. The most important part of the test was a comparison that we made as follows: We took two discs of chrome tungsten steel, surface ground and hardened them, and then tested three balls of each type, twelve in all, by applying a Brinell load of 3000 kilograms to each ball (one at a time), between the two hardened discs. We were able to test all twelve balls between the same two discs, merely adjusting the discs so that each succeeding impression would not strike the others. The surface of the discs were carefully polished and then lightly etched before the impressions were made. The diameter of the depression was measured in the usual way with a Brinell microscope and it was found that a given ball would always produce the same size depression on both discs, indicating that the discs were quite uniform in hardness. It was interesting to note that the ball that showed the highest scleroscope hardness also gave the smallest impression on the two steel discs which would indicate a higher hardness in the disc, supposing you were testing the disc rather than the ball. The most important feature of the test was the measurement of the deformation of the ball. The balls were all very carefully measured to one ten thousandths of an inch. After applying a load of 3000 kilograms, the balls were removed and by feeling with a micrometer, we were able to find the flat spots. The reduced diameter of the ball across the flat spots was measured, and, expressing it in terms of the percentage of the original diameter, we found that the ball of the highest scleroscope, deformed the least in the test, also indicated a higher Brinell hardness for the two discs. It would, therefore, seem that in testing hardened steel, it is desirable to obtain the hardest Brinell ball possible in order to get the figures which approximate the true Brinell hardness. A soft ball deforms under load and will give a large shallow impression indicating a low hardness. We obtained differences that ran up in the magnitude of 100 points in the neighborhood of 600 to 700 Brinell, hardness number depending on the type of ball used.

Mr. M. A. Grossman: How much were the balls deformed by the test?

Mr. J. J. Curran: I think the deformation amounted to between 0.3 and 1.0 per cent reduction in the original diameter, that is, the smallest measurement I could get across the flats would be from 0.3 to 1 per cent less than the original diameter of the ball.

Mr. S. Tour: The idea of the committee as I understand it, is to develop one particular hardness test, if such a thing is possible. As far as I can see, each particular hardness is a thing in itself, which measures something different. It is obvious that the Brinell test is different from the scleroscope test. To my mind, it is also obvious that we do not want a hardness test of one particular kind and abandon all the rest. The man in the shop using a tool does not care whether that tool is a certain scratch hardness or not. All that he wants to know is whether or not the tool will cut. Perhaps a scratch hardness has something to do with this property. I do not believe that it is possible to get one hardness test that will answer for everything that we want to test, but we have too many tests. It is unfortunate that we call them all hardness. I cannot imagine one type developed to correlate with another. We cannot call Rockwell so much Brinell, and we cannot call Brinell so much Rockwell. We can possibly develop other tests for specific uses which will be better than the tests we have at present. I doubt if we can develop one test that will eliminate the present tests or find any one kind of hardness that is going to answer for all, whether we call it hardness or something else. I have not been able to think of a good definition for hardness or for the different kinds of hardness. One speaker said something about correlating results of one hardness test to results of another. We cannot compare scratch with Brinell hardness. They are two different things, but we must decide what the proper scratch hardness is, and what it designates or some other thing to take the place of scratch hardness. We must decide what a Brinell test is and we must not forget the time element. We must decide what the Rockwell hardness is, what it measures, and if it is of value, use it. Then there are a number of different types of hardness which are similar. Some should be ruled out. In other words, if Rockwell hardness measures almost the same thing as Brinell hardness, and measures it better than Brinell hardness and answers the purpose better than Brinell, take Rockwell.

Mr. A. Hungelmann: Would it not be possible to formulate some instructions as to how to use different machines? You speak so much of the time element. I think the time element is just as important with metallurgists. The hardness is only one of the matters discussed at this convention, and no doubt many of us have not given the subject very much thought, but we would all be benefitted by a committee ruling as to the proper way to apply different tests for different purposes. I think we would all like to see that published.

Dr. Hollnagel: It would undoubtedly be possible to give such information with regard to a machine like the Brinell or Rockwell, but it would be quite impossible to offer anything with the present type of scleroscope. Before we could begin to tell that, we would have to make changes in the scleroscope. Before comparative tests thereon may

be had, one would have to make the impact for different materials the same. This could be done by reasoning along the same lines as one of the previous speakers referred to, that is to establish a specimen size such that the time of propragation wave in the specimen is the same. Furthermore, rebound will take place in approximately this time, and if the energy of the impactor is sufficient to exceed the elastic or ultimate limit, then one is still in the dark for some of this energy has gone into the indentation of the specimen and is lost as heat. This cannot give a true measure of the material as ordinarily taken. Resilience of deformed material rather than the resilience of original material is tested.

Mr. A. Hungelmann: I might ask Dr. Hollnagel if he thinks it is an impossible job to bring about these conditions?

Dr. Hollnagel: I am very glad to state that we have been thinking along this line. We hope it will be possible to make the time element the same in impact and rebound devices, and while we are not ready to publish such information, we have it in mind and are giving it very careful thought. I believe it can be done ultimately, but it is premature to make a positive statement at this time.

Mr. A. D. Flinn: I am not a steel treater or even the brother of a steel treater, so you must not take my remarks too seriously, but I do wish to congratulate your chairman and Dr. Hollnagel and the other members of the committee on the excellent work that the committee is doing. It is the kind of work which serves as an example of the thirty or forty committees working along similar practical lines. As I have been listening to Dr. Hollnagel's paper, and also your discussion, two words have run in my mind repeatedly, which no one here has used. One is relativity and the other is progress. Please do not think I am referring to Dr. Einstein's theory, for I know nothing about it, but rather that the engineer is always dealing with the relative. The physicist is a pure scientist, and deals with the absolute and basic fundamentals; but if our reasoning is not based on the last conception of the physical facts we are going to be misled in carrying out our tests or any other engineering processes. The word hardness is a common English word, and like all such words, it has certain meanings which we carry almost automatically into our so-called technical uses of these same terms. It may not be possible to meet the suggestion of the speaker, but I think it would be fortunate, if the committee could invent a new term. Let us not be afraid to do what the doctors and some of the other scientists do, take a term from the Latin or Greek, a word that will embody the results of the studies of our committee. I think it may be possible that it will not be one term but several terms which will eventually take the place of the word hardness. This discussion of scratch test impressions calls to mind a question concerning the meanings of common words. Some years ago a friend of mine, who was an amateur photographer, secured samples of a new developer with instructions which he followed, and got very unsatisfactory results. He tried again and again and being satisfied that he had done the best he could with the English language, and the materials, eventually went to a demonstration office, and asked to be shown how to use the developer. Among the instructions were these words "use a low gas flame," in a certain part of the process. He watched the man

start and noticed the size of his flame. He said, "You need go no further, if that is what you call a low flame." My friend had been using a flame about one-quarter of the size which the demonstrator used. This is an example of the meaning of a common English word. I am thinking the same is true of our scratch test. Furthermore, what was satisfactory so many years ago is no longer satisfactory because we have progressed. The method of 20 or 30 years ago can no longer meet the refinements of today, and we must change our terminology.

Mr. Rockwell: In dealing only with metals, ferrous and non-ferrous, according to our various ideas of what hardness is, we all know that no matter on what machine tests are made, we get high readings when we have greater hardness. I would like to ask Dr. Hollnagel whether or not he thinks that the time element can be made relative? Is it less with the hard than with the soft materials, and does it form a regular curve?

Dr. Hollnagel: That would have to be determined and it would unquestionably follow some form of regular function. For materials which are flat, the time element would be less than for materials which are rough. This would have to be investigated before one could tell definitely what should be the actual time element. There is as I understand it today, no definite specification on time in any of the material testing devices throughout the country. If you make a strength test for example, you turn the handle of a testing machine and await the drop of the bar. You use your own judgment. In some laboratories, of course, the one in charge stands alongside and says what is to be done. If the same specimen that has been run up in 1½, 2 or 5 minutes is run up in a time considerably less than that, the elastic limit will go up quite considerably beyond what it ordinarily is.

Mr. Rockwell: Would not that be a certain line of work for the committee, say, simply to specify 20 seconds for soft metals for the Brinell test, and 15 seconds for hard metals?

Dr. Hollnagel: It would be rather an unfortunate thing to have a range of time for different degress of softness or hardness, that is, if one could standardize on the time of application of stress and have the entire scale for a given instrument and kind of material, then it would seem that a correct comparison could be had straight through. The other plan would give so many different results that a given hardness would mean little. It would seem better to standardize on the time for a material and let the load be variable for material. Of course, that brings up the question as to size of ball for a given load, but certainly we can correlate the results obtained for different sizes of ball, with comparative ease. It is only a question of working until a relationship is arrived at which is desired, and if proper time limits be agreed to, proper correlation should be possible. Until that information is at hand, one is quite in the dark.

Mr. Beamont: It is my opinion on this testing that it is misleading to believe any of the information gotten by applying testing machines to any definite work; the conditions alter so. For instance, the Rockwell machines are absolutely unfitted on certain classes of work, such as forgings, owing to the surface conditions of the steel; a scleroscope is likewise absolutely unfitted for such work because it is impossible to get data. A file as a testing machine is, I believe, the most reliable at

present. Another method of testing is the Brinell. As regards terms of hardness, I think we have worked this down to a very fine point, but possibly, Rockwell and Brinell all really do define the self same thing. I think the difference in the machines in their readings is simply because they read differently something proportional to the same properties and therefore cannot get the same results. Arriving at a result by rebound cannot be the same as by a penetration of a ball to a 1/16 inch. It may be that we will need many kinds of hardness for we are arriving at different conclusions by different methods.

Dr. Hollnagel: I am in entire accord in regard to being able to utilize instruments on rough castings; when it comes to the question of standardizing hardness tests of any sort, it will have to be done on surface of comparable character, prepared the same; then will tests be comparative. One should neither polish the surface nor leave it rough; the surface should be somewhere between the two in nearly every case. As to all three machines measuring the same I am afraid I will have to take issue. A scleroscope does not measure the same thing that a Brinell or Rockwell machine does. The scleroscope returns to the tup of a certain amount of energy which ordinarily in testing materials is spoken of as the energy due to resilience and which is certainly quite a different thing from what happens when one drives a piece of "hard" metal into a specimen. Take a Brinell depression specimen, cut a section across it, polish and etch it, and examine it under the microscope—a very interesting field is open to you. You will find successive layers of compression just as clear there as you do boundaries in different stages of steel. This does not result in scleroscope test when the material does not show marked permanent set. It does result to a very minor degree when slight permanent set appears.

Mr. G. W. Walker: I have noticed at different times statements in regard to time element in use of Brinell machines. One statement was that the load should be applied for a minute, another for half a minute, etc. I am wondering if anyone has determined what difference is made in the hardness number for varying periods of time that the load is applied, whether a minute or half a minute.

Dr. Hollnagel: We have not made any tests which would make possible an answer to your question, but we have satisfied ourselves that time and application of stress do affect the number. We probably will in the near future do something along that line to definitely establish it. I might say also that any type of machine, which applies the pressure in a pulsating manner would not be anywhere near as good as the one that applies a constant load. They are also those which provide pressure by centrifugal pump; this reduces the magnitude of the impulse and more nearly approaches constant duration of stress.

Mr. Walker: In consideration of this whole matter of hardness, it seems to me that first we must agree as to the definition of the term hardness and having agreed, we must define all of the conditions under which the tests must be made, such as time, pressure, etc., or whatever is necessary, and then go to work and construct a machine accordingly. It is only after we have defined conditions that we will be able to get any reliable results. I remember seeing in Edison's "Engineering Steels," a statement that a piece of drill rod properly hardened and with

the end ground off square, was a much better means for determining "file hardness" than a file.

Mr. Beamont: This test has been carried out in the plant of Indianapolis Ball Bearing Co.

Dr. Hollnagel: Can you say how nearly reproducible the results are after each grinding or for different drill rods?

Mr. Beamont: No.

Dr. Hollnagel: Material is very apt to change from grinding to grinding. You would have a different character as you went along. If the material is not ground enough, you can put amorphous material across the surface and by too fine grinding, change the character of it, but if it is comparatively rough and satisfactory in this form, you will probably be fairly successful.

Unannounced Speaker: Answering the question as to whether it makes any difference as to the time of load in a Brinell test, would say, that about five years or more ago I was experimenting with some rail steels and investigated that question to the best of my ability and found that the irregularities in the steel dies which I was using caused a greater difference in the depression than any difference which I could find due to leaving the load on 15 seconds, 30 seconds, 45 seconds, a minute or even a day. However, fairly large variations could be had by pumping up quickly or slowly. Mr. Archer of the Aluminum Co. of America recently told me of an instance where he took a very well made and uniform piece of aluminum alloy, fairly soft, Brinell A perhaps, broke it up into several parts, sent to several laboratories which reported hardness plus or minus 80 and 20. He thought the difference was due to the difference in speed at which load was applied. If in A type Brinell you raise the rate very rapidly you will get more than the theoretical thousand, and consequently a larger depression.

Mr. Curran: In connection with what the previous speaker has said, I wonder if some of the variations were not possibly due to flatness of the balls used by the different men. I have found this condition in plants that I have gone into. For hardness testing work, we try to make conditions ideal. I have been in plants where they use the ordinary hydraulic type of machine, and I have found that it is rarely possible to check results. The average ball in daily use is not round. Some show signs of severe wear, having been used so often. It is folly to take a ball and use it for soft material, then hardened material, and then back to soft material and hope to check previous results with it. In connection with Mr. Walker's question about the effect of time, I recall having heard a paper on this subject, although I am not certain at what meeting I heard it, but I believe it was the last meeting of the American Institute of Metals in Boston some five or six years ago, in which it was stated that in soft materials, it was possible to get variations in the size of the impression by holding your load for different lengths of time up to fifteen minutes. In our regular practice I doubt if any variation in time between fifteen seconds and a minute on ordinary steel will produce differences in observed hardness. It may produce a difference in the reading, which the average Brinell microscope would not indicate, being within the limits of error in reading.

Chairman Bellis: As a rule, as carried out, Brinell tests are not closer than ±5 per cent, according to Foss and Brumfield.

Mr. H. B. Northrup: I believe I have a point of view which some are overlooking in the question of hardness, whatever definition you may have for hardness. There has been an article written recently which stated something about the specifications which did not specify. In my opinion, there are two kinds of hardness; hardness which you will desire to use in writing a specification for material to customer and hardness which you want to use in inspection. I believe they are entirely two different things. Taking the first hardness, which you wish to use in specifying a certain hardness on a certain piece for a certain customer, who may specify material is to be 300 Brinell hardness number. In that case, I believe it is highly desirable that the ball be standardized so that you get a certain definite standard hardness of ball to be used in a testing machine, specify the load that is to be applied and the duration of the load. On the other hand I believe that the various methods of hardness which have been devised and which are in constant practice, as an inspection method has its practical application; for instance, a man may wish to test a piece by what he terms hardness for inspection purposes by the file. Agreeing with Dr. Hollnagel, I believe that the file test should be standarized in the shop where you wish to use it as an inspection method. That file test used on that paricular piece is probably the only test that can be applied. For instance, I know of some automobile work where they specify the size and kind of file. They also specify that the file be used with moderate pressure and if the piece is harder than the file, the file will be marked. I have seen inspection methods where a file is used, where a 200-pound man laying on a piece of steel clamped in a vice will call that piece not file hard if he can at least scratch it. If he would use common sense in applying his pressure, and notice his file he would have reported differently. Grinding off material will have some direct bearing on the resulting test. Am not inclined to believe in the use of drill rod as a testing medium. Am inclined to specify for inspection purposes a certain file test piece with a file and in making the test observe the file as well as the piece. If the piece for inspection purposes withstands a file used under the directions of common sense and that piece is to be used in a certain part of a given machine and withstands the test, that is all you desire. On the other hand, if you are going to write the specifications for the use of a certain given testing instrument you must standardize it.

I had occasion recently to make some tests which did not agree with the mill and we rejected the stock. The mill came back and wanted to know the rate of application of the load. This subject has been raised this morning numerous times. We gave them the rate of the application of the load, and next coming down to a common process, they checked our results and substantiated our rejection of that stock. Their rate of application was different from ours, and we were working at, you might say, opposite ends. Something can be offered in specifying hardness. We have recently installed in our shop the Rockwell machine. We have the latest Brinell Alpha machine which I thought was pretty good. We have the scleroscope and we have files. There is a lot of beating around the bush about specifications that do not specify, and

bringing up my original point, there are two kinds of testing for hardness, one for specification and another for inspection.

Dr. Hollnagel: I think Mr. Northrup's specification of putting common sense into the test is rather an elastic one, but I think he brought up some very good points and am glad they have been called to our attention. We are making some apparently destructive criticisms, but we are trying to get to the bottom of limitations on present processes. It is necessary to take a somewhat extreme viewpoint.

Mr. H. B. Northrup: As an illustration of that point of the use of the scleroscope for an inspection: During the war we had to specify for inspection purposes certain scleroscope hardnesses on certain pieces of carbon steel. In one part of the light Browning rifle, we had a certain scleroscope hardness test, part of the instrument was not standing up. In discussing this with Mr. John Browning he stated that you don't need a scleroscope to tell you what the correct hardness of that piece is. All you need is a vise and hammer and common sense. You can't break every piece, however. We used a scleroscope and obtained the nearest reading we could to a piece he said was correct for the gun.

Mr. G. W. Keller: I have noticed some exceedingly critical remarks on method of testing one against the other. I think for the work to be a benefit as a whole, we must put aside our personal criticisms of methods, recognize that the principle of Brinell and Rockwell is slightly different from the scleroscope, but each of them have one fundamental method which we must develop. We must take what the scleroscope has to give us and not see its limitations but what we can do to perfect each machine.

Dr. Hollnagel: It is a pretty well known principle that before you can construct you must destroy. We, therefore, must give destructive as well as constructive criticism. We do not aim to make decisions on behalf of any type of so-called hardness tester. In regard to Mr. Northrup's common sense, the committee is not a psychological body and cannot analyze common sense. Common sense is a characteristic of the individual. Moderate pressure applied to a file. What is moderate pressure? It may mean one thing to a child, another thing to a woman, and so on. These terms are purely relative. We cannot deal with any specifications of such indefinite character. Give us something in terms of which we can define terms such as moderate pressure and common sense and our committee will be only too glad to give it consideration.

THERMAL TRANSFORMATIONS IN SOME CHROME-VANADIUM STEELS[1]

By J. S. Vanick and W. W. Sveshnikoff

Abstract

A study of the movement with changes in composition, initial temperature and rate of cooling of the thermal transformations in a series of chrome-vanadium steels was made, and correlated with difference in hardness and microstructure, to indicate possible changes in constitution. A chrome-vanadium composition of the forging type (i. e., .30-.40 per cent carbon; 1.0 per cent chromium and .18 per cent vanadium) was used as a pivoting composition. One of the important elements was varied while the remaining two were kept constant. Carbon was varied from .16 to 1.16 per cent; vanadium from 0.0 to .65 per cent; chromium from 0.0 to 21.0 per cent. Three additional steels were added to illustrate the influence of the .30 to .40 per cent carbon range and the effect of the common impurities, namely manganese, silicon, etc.

Increasing the carbon content from .16 to 1.16 per cent, lowers the positions of the transformations; which remain, however, some 10 to 30 degrees Cent. above those for the corresponding alloy-free, steels. Ac_2 occurs above Ac_1 in the low carbon steels. Increasing the initial temperature from 850 to 975 degrees Cent. lowers Ar but 12 degrees Cent., indicating that the solution of the elements is practically complete at 850 degrees Cent.

Increasing the vanadium content from .025 to .65 per cent, produces a small displacement of the transformations. A-1 is raised approximately 5 degrees Cent. for each 0.10 per cent vanadium. A-3 is obscured in the thermal curves but revealed in the hardness curves. Thermal and hardness data indicate that the solution of the element or its compounds is accomplished between 850 and 900 degrees Cent. Cooling from the latter temperature and 975 degrees Cent., does not displace the Ar transformations.

Increasing the chromium content from 0 to 21.0 per cent produces a gradual rise in Ac_1, effecting a junction with Ac_2 at .75 per cent chromium, and Ac_3 at 3.1 per cent chromium; continuing its rise to 7.7 per cent chromium, then remaining constant. Meanwhile Ac_2 remains constant to 7.7 per cent chromium, then begins to fall. These facts are explained by supposing the chromium enters the carbides until approximately 7.7 per cent has been absorbed, whence the excess passes into the ferrite.

The split transformation appears feebly, at 2.0 per cent and strongly at 7.0 per cent chromium, for the cooling rates used. Increasing the cooling rates or raising the initial temperatures suppresses or lowers the transformations. These effects, upon cooling from fixed temperatures at increasing rates, are attributed to the re-

A paper presented before the Detroit convention of the society, October 2-7, 1922. Of the authors, J. S. Vanick is research operator, Fixed Nitrogen Research Laboratory Department of Agriculture, and W. W. Sveshnikoff is assistant physicist, Bureau of Standards, both of Washington, D. C.

1. Published by the permission of the director of the Fixed Nitrogen Research Laboratory, Department of Agriculture, Washington, D. C.

tarding action of chromium in solution while the effects produced by cooling from higher initial temperatures are attributed to the dissociation of carbides and the distribution of their components.

The structures which accompany the various thermal changes indicate that the combined Ar_3-$_1$ transformation occurs in segments when Ar′ and Ar″ appear as distinct inflections.

IN THE course of an investigation of a series of chrome vanadium steels, it became desirable to determine such physical characteristics as some of the methods of thermal analysis would yield. The range of influence of certain of the variables involved in the thermal study is quite broad, on account of the sensitivity to thermal changes of some of the steels. The records of thermal behavior are for this reason, quite necessarily limited to the particular phenomena under investigation. It is the purpose of this paper to present some of the results obtained in the thermal analyses of a series of chrome-vanadium steels with the object in view of adding to the information now available.

The steels selected for this purpose consisted of the series listed in Table I. As indicated in the table, the series lends itself readily to a division into 3 groups each of which comprises a variation in the concentration of one of the alloying elements. Inasmuch as manufacturing practice limits the commercial application of these steels, the range of compositions were chosen to lie close to those of available commercial steels.

The steels (20) which were used in the following experiments were made by the electric furnace process. The necessary ferro-alloys were added in the ladle, to the liquid metal which was subsequently cast into ingots and rolled into bars. Specimens for thermal analysis were cut from bars which were previously annealed at 1000 degrees Cent. to remove possible thermal effects which may have been introduced in the preparation of the steels.

Thermal curves were obtained by the inverse rate method with the apparatus (2) available for this purpose at the Bureau of Standards. The samples used in these tests were roughly 10 x 10 x 2 millimeters in size, slotted to the center to receive the thermocouple. The temperature gradient throughout a specimen of this size is negligible. The heating and cooling was conducted at a rate of .10 to .16 degrees Cent. per second. This rate is a normal one for an alloy-free steel of a corresponding carbon content. More rapid rates would cause an appreciable displacement of the transformation in certain of the steels. Cooling curves were taken immediately after the maximum temperature for the particular specimen was reported. The time interval during which the specimen remained at the temperature from which cooling began was consequently very short.

The details of manipulation described above, are mentioned in view of the sensitivity of steels of this type to small variations in the initial temperature, time at temperature and rate of cooling. It was desired to maintain conditions as nearly uniform as possible in order that the influence of changes in composition and to some extent the effect of varying certain physical factors might be observed.

In some cases several heatings and coolings were made for each curve

and the results plotted as shown in the following figures. Each point in the curves represents an individual observation. The slight roughness which the curves show in places is caused by small observational errors

Table I

Compositions of Chrome Vanadium Series of Steels

Mark	C.	Mn.	P.	S.	Si.	Cr.	V.
Carbon Group							
11	.16	.55	.023	.023	.34	1.03	.20
1	.30	.68	.012	.024	.26	.93	.18
12	.58	.68	.011	.017	.23	.73	.18
13	1.16	.55	.022	.018	.20	1.06	.20
Vanadium Group							
14	.40	.53	.018	.023	.18	1.05	.025
7	.37	.52	.018	.018	.20	1.05	.07
1	.30	.68	.012	.024	.26	0.93	.18
9	.37	.55	.018	.019	.18	1.07	.31
10	.27	.34	.025	.011	.29	1.24	.65
Chromium Group							
A	.33	..	...	.007	.009	...	..
B	.34	.55	.030	.032	.14	...	..
C	.40	.75	.010	.034	.22	...	..
2	.38	.39	.017	.022	.27	.04	.19
3	.29	.53	.015	.011	.16	.51	.28
1	.30	.68	.012	.024	.26	.93	.18
4	.31	.48	.011	.011	.12	2.01	.34
5	.33	.37	.028	.013	.26	7.70	.18
6	.42	.35	.025	.009	.06	14.40	.18

which would extinguish each other if the differences were balanced.

Thermal Transformations in the Carbon Group

Transformations Upon Heating

Fig. 1 shows the influence of carbon upon the thermal transformations in a steel of a typical chrome-vanadium composition. A comparison of the curves representing specimen B of Fig. 2 with those of steel No. 1 of Fig. 1 illustrates, directly, the raising of the Ac and Ar transformations with the exception of A-2 by the presence of chromium and vanadium. The influence of chromium in this respect, has been observed by Osmond (1) and confirmed by others. A similar property has been associated with the addition of vanadium.

The increase in carbon is accompanied by a gradual lowering of both Ac_1 and Ac_3, but the increased degree at which the latter is lowered results in its combination with Ac_1 at a composition of less than .60 per cent carbon. With an increase in carbon from .58 to 1.16 per cent the temperature positions of the transformations remain unchanged. Although the temperature of the maxima of the transformations and the range within which the transformations proceed are lowered by the increase in carbon the resulting positions, both on heating and cooling remain some 10 to 30 degrees Cent. above the ranges for the corresponding alloy-free, carbon steels. A comparison of steels B and C, of Fig. 2, with steel No. 1, of Fig. 1 illustrates the relative divergence.

CARBON GROUP HEATING AND COOLING CURVES

Fig. 1.—Shows the influence of carbon upon the thermal transformations of steel of a typical chromium-vanadium composition. Chemical composition—Carbon, 0.16 per cent; chromium, 1.06 per cent; vanadium, 0.18 per cent.

Transformations Upon Cooling

Griffiths (4) reported results similar to those above on heating a carbon series of chrome-vanadium steels but further reported a considerable lowering of the transformations on cooling, roughly in proportion to the initial temperature from which the steel was cooled. Fig 9 illustrates the 12 and 21 degrees Cent. lowering of Ar_1 and Ar_3 respectively with a 125 degree Cent. difference in initial temperatures. With greater amounts of carbon, the position of the Ar_{1-3} transformation is much less affected by changes in the initial temperature of heating. These relations hold for the cooling rates compared. Obviously a more rapid rate of cooling would produce a further lowering of the transformations.

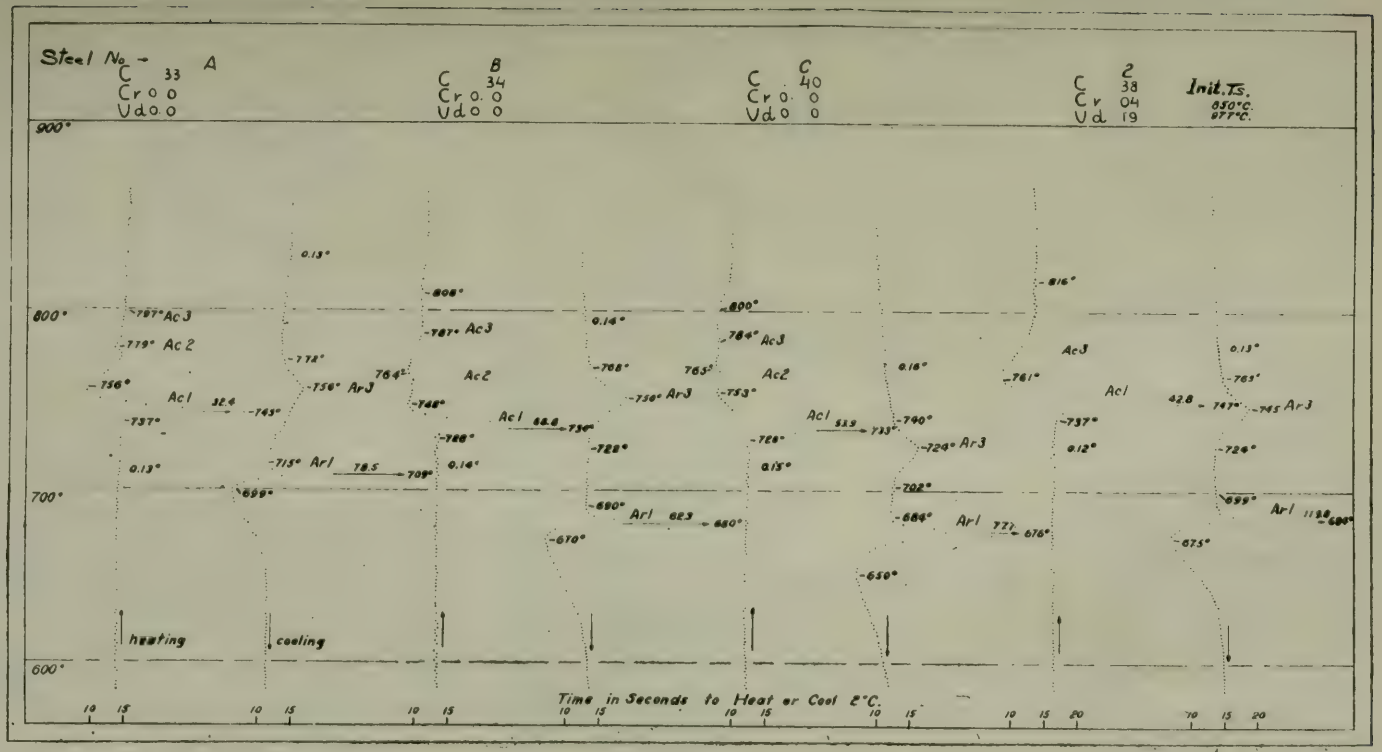
The influence of carbon in overcoming the resistance introduced by the added elements, to the Ar_1 change is evident in a comparison of the amplitudes of this transformation. When the amount of carbon is appreciably increased as in steels No. 12 and 13, the solid solution, being more concentrated in carbon, promotes the precipitation and coalescence of the carbide. The uniformity in the temperature range within which the Ar_1 change occurred, suggested the preparation of Table II, to list the relative variations in the intensity of the Ar_1 change. A progressive increase in amplitude, allowing for the additive effect of Ar_3 in steels 12 and 13, with an increase in carbon, indicates the dominance of carbon in determining the position of this transformation in these steels.

The influence of the alloying elements upon the Ac_1 or carbide transformation is significantly expressed in the relative positions of Ac_1 and Ac_2 deflections. In the low carbon steels, Ac_2 occurs at a lower temperature than Ac_1. Its position in the curves was determined by its characteristic appearance, its magnitude and constancy of position in the critical ranges.

The occurrence of Ac_2 below Ac_1 had been reported by Moore (5) for chromium steels containing more than 3 per cent of that element, and by McWilliam and Barnes (6) for steels carrying 2 per cent chromium. In view of the low chromium content its unusual position in this series of steels is doubtless assisted by the influence of vanadium. The latter effect is more clearly shown in the vanadium group of steels.

The constancy in position and magnitude of the change to Beta iron both on heating and cooling marks the degree of independence of this transformation, of the A-1 change. Since the A-2 change is an allotropic one, not involving a change in phase, the physical properties, other than magnetic or electrical, are not appreciably altered.

The peculiar behavior of the A-2 change in the low carbon steels merits further consideration. Although the transformation appears to proceed, unhampered by the condition or constitution of the phases active in the critical range, there is little doubt but what the thermal disturbance is of sufficient intensity in many cases, to provoke the occurrence of a phase-change transformation which had been delayed by supercooling. The significance of the A-2 change in pointing toward changes in the constitution of some of these steels is mentioned in one of the subsequent paragraphs.



INFLUENCE OF UNUSUAL IMPURITIES INCLUDING VANADIUM UPON TRANSFORMATIONS

Fig 2 is a comparison of the transformation curves of steels A, B, C and 2. The composition of these steels is shown on the chart.

Relation Between Transformations, Hardness and Structure

The relation between the transformations and the hardness of quenched specimens is illustrated in the curves of Fig. 3. Hardening, in the low carbon steels is accomplished in two steps; one, corresponding to the solution of at least a portion of the carbides at Ac_1 and a second, corresponding to the further solution and dispersion of the dissolved elements, at Ac_3. The latter effect marking the end of Ac_3 is significant in the study of steels in which this transformation is feebly expressed in the thermal changes. Where the two transformations are combined, a marked increase in hardness accompanies their progress,

Table II

Intensity of Ar_1 Transformation

	——Composition——					Temp. Range of Ar_1	Amplitude in seconds	Sec.
No.	C	Cr	Vd	Rate	Ar_1 T.	Degrees Cent.	at Ar_1	.01% C.
A.....	.33	..	..	.13	709	699-715	78.5	2.38
B.....	.34	..	..	.14	680	670-690	82.3	2.42
11.....	.16	1.03	.20	.13	694	682-700	52.8	3.30
1.....	.30	.93	.18	.13	697	685-703	85.9	2.87
12.....	.58	.73	.18	.12	690	682-703	148.1	2.60
13.....	1.16	1.06	.20	.11	692	676-700	174.3	1.50

as shown in the curve for steel No. 13. An increase in hardness in specimens quenched at temperatures, increasing progressively, above Ac_3 apparently marks the distribution of carbon in the iron-chromium solvent; the more thorough dispersion produced by the higher temperatures.

The structures of the carbon group of steels generally resembles those of the corresponding alloy-free, carbon steels. A brief description has been given in an earlier presentation (20).

Thermal Transformations in the Vanadium Group

Transformations Upon Heating

The thermal effects produced by varying the vanadium content of a chrome-vanadium steel, are shown in Fig. 4 and recorded in Table III. An examination of the curves shows that the changes in the positions of the transformations, in the composition range investigated, are small. If a comparison be made between curves B and C of Fig. 2 with curve 2 of the same figure, a slight rise in the position of Ac_1 is evident. This change may be attributed to the presence of vanadium, although a correction for the influence of silicon and manganese in respectively raising and lowering this transformation, must be considered.

The vanadium addition, probably in the form of a complex carbide, is effective in retarding the Ac_3 transformation, such that the heat absorption accompanying the solution of the element in the gamma iron solvent, is difficult to locate in the thermal curves. A portion of the heat absorption is contained in Ac_1, but a greater portion seems to be

Table III

Thermal Data

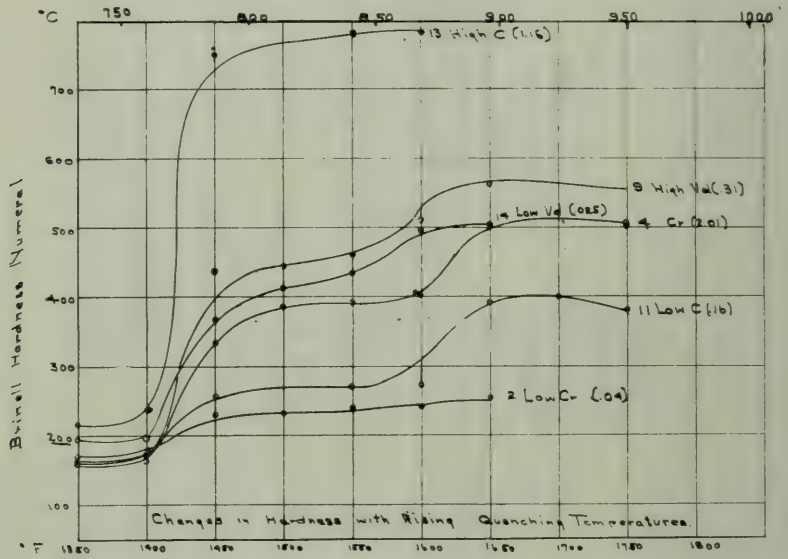
Vanadium Group

No.	Composition C	Cr	V	Ac-1	Ac-2	Ac-3	Temp. Degrees Cent. (Initial)	Ar-3	Ar-2	Ar-1	Ratio Cr:C	Cr+V:C	Amplitude Ar_1
14	.40	1.05	.025	758	...	...	975	706	...	694	2.6	2.7	128
7	.37	1.05	.07	762	...	...	975	711	706	696	2.8	3.0	139
1	.30	.93	.18	768	764	807	975	747	...	697	3.1	3.4	86
9	.37	1.07	.31	772	766	...	975	717	...	696	2.9	3.7	113
10	.27	1.24	.65	781	768	834	975	786	768	713	5.2	7.6	55
							Carbon Group						
11	.16	1.03	.20	776	766	827	975	783	766	694	6.6	7.8	53
							Chromium Group						
2	.38	.04	.19	747	...	...	975	745	...	684	..	..	120
							Alloy-Free Group						
B	.40	...	..	733	765	784	975	724	...	676	..	..	78
C	.34	...	...	734	764	797	975	750	...	680	..	..	82

concealed in the faint, but continued heat absorption above Ac_1.

The position of Ac_2 with increasing vanadium is inverted when 0.18 per cent of the element has been added. The transformation retains it's temperature position with the addition of vanadium. The separation of Ac_2 from Ac_1 is caused as previously mentioned, by the progressive resistance to solution of the complex carbides which form, and the constancy of the change from alpha to beta iron irrespectively of the influence of the small amount of added elements.

That the thermal disturbance at A-2 is active in precipitating the Ac_1 transformation is apparent from the curves for steels 1, 9 and 10. In steels 1 and 9, Ac_2 had occurred within the Ac_1 transformation range, as indicated by the sudden heat absorption. In steel 10 the sharp heat



CHANGES IN HARDNESS WITH RISING QUENCHING TEMPERATURES

Fig. 3.—The hardness of the high and low vanadium steel are shown in the above curve. A study of the curve shows that sharp increases in hardness is obtained in passing Ac_1 followed by a second increase at higher temperatures.

absorption at Ac_2, was sufficient to precipitate the Ac_1 change which existed in a slightly super-heated state at the temperature of Ac_2. When the amount of alloying elements is sufficiently large, A-2 occurs independently of the remaining transformations due to its lowering and an attendant raising of Ac_1.

Transformations Upon Cooling

In cooling, the upper transformation appears to be slightly raised, but the movement with changes in composition, is more directly related to the variations in the carbon content or the chromium to carbon ratio, which is determined by the carbon content. This effect is revealed in a comparison of the position of the transformations in steel 11 of the carbon group, with steel 10 of the vanadium group. The 0.08 per cent increase in carbon in the latter, is nearly sufficient to balance the influence of the 0.58 per cent vanadium addition.

The level of the Ar_1 transformations remains some 15 to 20 degrees

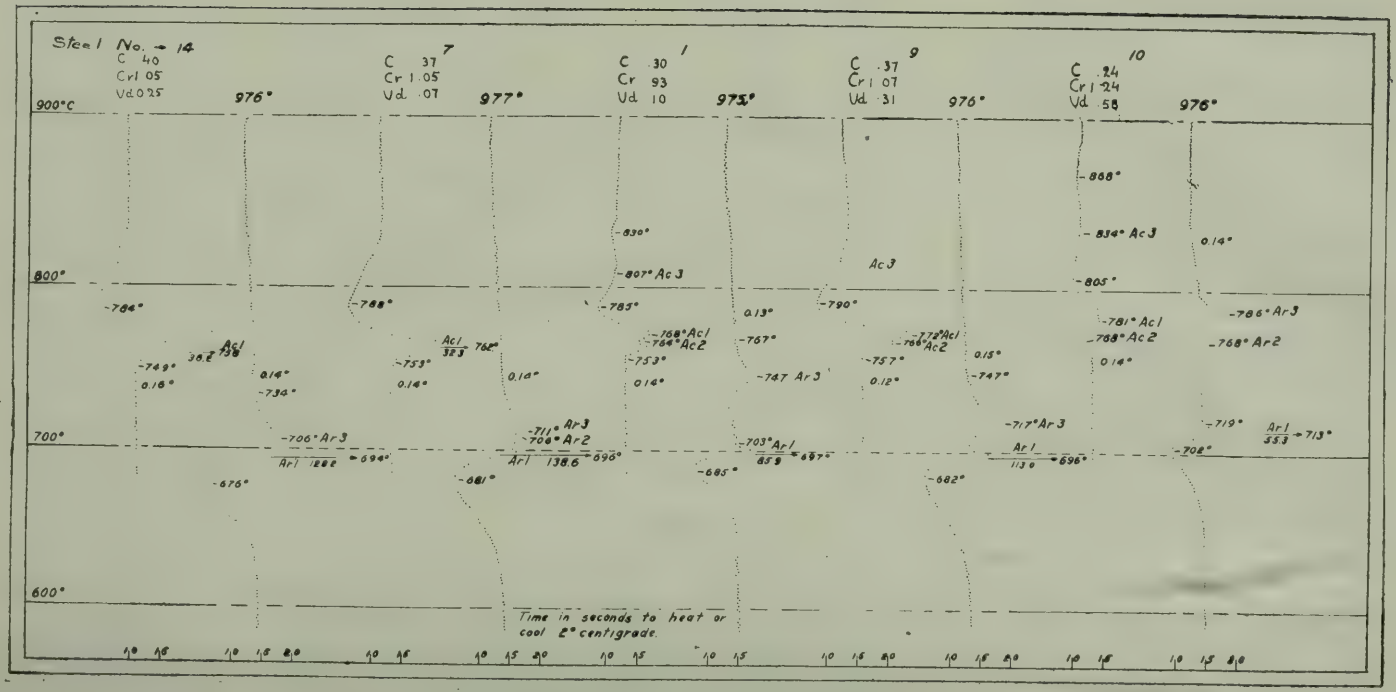
Cent. above the corresponding level for equivalent alloy-free carbon steels, and rises rather abruptly for the 0.65 per cent vanadium steel. This slight departure from the normal position of this transformation agrees with the results obtained by Pultz (7) and later by Norris (8), which show a 10 degree Cent. rise for a 0.20 per cent addition of vanadium to a plain carbon steel. Pultz further reports that "additions of vanadium up to 0.98 per cent have no effect upon Ar_1 but Ar_{3-2} is raised in proportion to the amount of vanadium added." The 0.5 degree Cent. rise for each 0.01 per cent vanadium appears to be repeated in the Ac_1 transformation for these chrome-vanadium steels. If, for example, steel 14 (Fig. 4) containing very little vanadium is compared to the curve of steel 2 (Fig. 2) a slight rise in the position of Ac_1 is evident, which is apparently caused by the difference in chromium. An examination of the positions of the Ac_1 points in the vanadium group, shows an increase of approximately 0.5 degrees Cent. for each 0.01 per cent of vanadium. This change represents the combined effect of the variations in composition and a slight allowance needs to be made for difference in chromium and carbon.

Significance of Changes and Relation to Hardness and Structure

The tendency of vanadium to combine with the carbide formed in steels, has been reported in the work of Arnold (9) and is quite generally known. This tendency is not prevented by the presence of chromium. Apparently a complex carbide of iron-chromium occurs, due to the replaceability of iron in the carbide by vanadium and chromium. This effect would be thermally indicated in the distortion or displacement of the transformations. The amplitude of the Ar_1 transformation which marks the intensity of the change during the carbide precipitation remains quite proportional to the amount of carbon involved in the change, thus expressing the dominating influence of this element upon the course of the change. This is further shown in the unaltered temperature position of the transformation, for a vanadium content up to 0.30 per cent. A comparison of the data in Table III shows an increase in temperature and amplitude for the alloy steels. The changes in amplitude are not consistent with the changes in composition. For example, a comparison of steels 7 and 9, which are nearly identical in composition with the exception of the vanadium difference, shows a decrease in intensity of Ar_1. This is compensated for by the greater spread between the beginning of Ar_2 and the end of Ar_1, indicating the separation of the compounds through a considerably increased temperature range. No evidence of a slackening of arrest in the displacement or distortion of the transformations could be located that would suggest a constitutional change.

The rise in Ac_1 with an increase in vanadium showing a resistance to the solution of this element or its compounds has been mentioned above. Apparently a complete solution, for the quantities present, is accomplished between 850 and 900 degrees Cent. Cooling from these temperatures and 975, does not produce an appreciable displacement of the Ar transformations. Changes in the hardness of specimens quenched from various temperatures over the critical range, support this view.

The hardness of a high and low vanadium steel, as presented in Fig. 3, shows a sharp increase in passing Ac_1 followed by a second increase at



VANADIUM GROUP HEATING AND COOLING CURVES

Fig. 4 shows the thermal effects produced by varying the vanadium content of a chromium-vanadium steel. An examination of the carbon shows that the changes in the position of the transformations in the composition range investigated are small. The composition of each steel is recorded on the chart.

higher temperatures. A partial dissociation of the carbides at the lower temperature, is evident. Although the Ac_3 transformation appears but feebly in the thermal curves, its position is quite decisively located in the hardness curves. The increase in hardness produced by quenching from temperatures above Ac_3 is doubtless due to the progressive dispersion of the dissolved elements. Structures of quenched specimens are martensitic, and no evidence of a free constituent is detectable.

The structures, in general, resemble those of the corresponding carbon steels. The concentration of vanadium in the carbide of annealed specimens, is amply illustrated by comparing Figs. 5 and 5a, the latter showing the carbide constituent collected into a thin network of globules.

Thermal Transformations in the Chromium Group

The chromium group of steels might well be separated into two divisions, one comprising small increments, to a total of 2 per cent of the added element and a second division comprising large increments, as represented by the 7, 14, and 21 per cent chromium steels. The narrow range of carbon contents, the disturbing effects of vanadium and the usual impurities, prevent the direct application of some of the results, to the amplification of the chromium-carbon system.

However, the dominating influence of the chromium on the properties of the steels makes a description and discussion of the thermal transformation on the basis of the present state of the ternary iron-carbon-chromium system, desirable.

Recent work by Edwards (10)-(11)-(12), Murakami (13), Monypenny (14) Daeves (15), Russell (16), and others has added many facts to our knowledge of the constitution of the iron-carbon chromium system and the peculiar behavior of its alloys under various thermal treatments. However, the unstable position of our knowledge of the chromium alloys emphasizes the need for additional facts which may be used in charting the influence of this important element.

The early work of Osmond* indicated important changes in the behavior of the thermal transformations with the addition of chromium, as for example, the raising the Ac_1 points with an increase in chromium.

Transformation Upon Heating

The influence of chromium on the transformations upon heating is shown in the curves of Fig. 6.

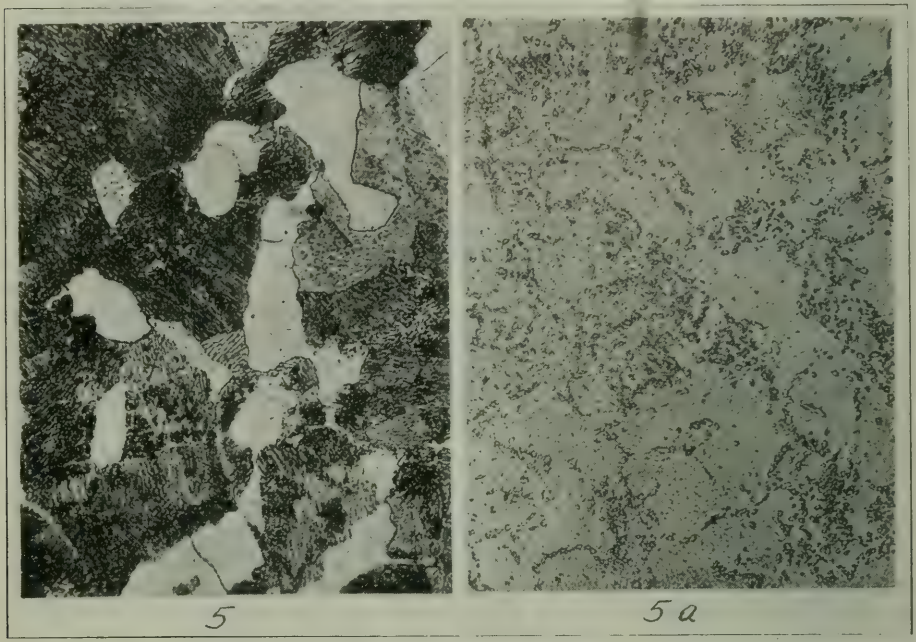
As previously mentioned, the addition of chromium to a carbon-vanadium steel, raises the critical points to a degree suggesting the cumulative action of the two alloying elements. A gradual rise in Ac_1 marking the solution of a portion of the carbides, is evident. When the quantity of chromium exceeds two per cent, the rise becomes more pronounced as shown in curve No. 5, but the rate of increase is not sustained with a further addition of chromium.

At a position representing a concentration of ¾ per cent chromium, as interpreted from Fig. 8, Ac_2, which remains comparatively fixed on heating and cooling, is joined by Ac_1 to form a single inflection. Obviously, a change in composition would slightly shift the junction of the two transformations. The lowering of the Ac_1 range with a slight increase

*Ibid.

in carbon and the effect of greater amounts of chromium in lowering the A-2 transformation would be expected. Up to this point, chromium appears to enter chiefly into the carbide, as marked by the Ac_1 rise, leaving little evidence of an iron-chromium solution.

An indication of the iron-chromium solution is found in the marked lowering of the A-2 change. The rate of lowering with an increasing



MICROSTRUCTURES

Fig. 5.—Photomicrograph of an annealed low vanadium steel (0.025 vanadium) x 500. Fig. 5a.—Photomicrograph of an annealed vanadium steel (0.58 vanadium) showing the carbide constituent collected in the fine network of globules x 500.

chromium content, is more rapid than that reported by Murakami* for the change in position of A-2 with additions of chromium to iron, thereby suggesting that the remaining impurities, notably silicon and vanadium exert a similar influence upon the depression of the transformation. Since A-2 is not accompanied by a phase change its behavior in the thermal curves might be disregarded. However, the intimate relation between the A-2 change and the alpha to gamma change, make the former extremely helpful in indicating changes in the latter.

If, for example, the vanadium content be ignored, most of the chromium up to 7.7 per cent appears to enter principally into the carbide as indicated in the impedance of the carbide solution and alpha to gamma change. The temperature for Ac_1 rises to 819 degrees Cent. which is roughly 100 degrees Cent. above the corresponding change in an alloy-free carbon steel, while the Ac_2 change which effectively marks

*Apart from the characteristic appearance and small thermal disturbance produced, the identity of the A-2 change was verified by repeated heating to temperatures slightly above the Ac_2 position. In each case the reverse transformation occurred in cooling at a temperature within a degree or two of that observed in heating, thus revealing the reversibility which is characteristic of this particular change.

the influence of chromium on the iron, is lowered about 5 degrees Cent. by the same amount of the element. A further increase in chromium to 14.4 per cent (as in specimen 6) raises Ac_{1-3} but slightly, while A-2 is appreciably lowered. This phenomenon immediately suggests the formation of a limiting compound of carbon and chromium near the 7.7 per cent composition and the release of the surplus chromium into the iron to form an iron-chromium solution. The rise in Ac_1 is due, no doubt, to the retarded solution of chromium-iron carbides but in arriving at 7.7 per cent chromium the slight lowering of Ac_2 below the carbide solution temperature indicates the presence of an iron-chromium solution in which chromium is lowering the temperature of the alpha to gamma conversion. The 20:1 chromium to carbon ratio which is represented by this composition closely agrees with the formula (Fe_3C: Cr_4C) for the gamma carbide proposed by Murakami*. The presence of this compound would account for the high position of Ac_1

The composition of the carbides which appear in chromium steels is disputable, and an estimate made from these few alloys would be hazardous. It appears quite certain that a transition from Fe_3C to some carbide such as Cr_4C or Cr_5C_2, occurs in which chromium gradually replaces iron when equilibrium conditions have obtained. Edwards and Norbury (12), by means of resistance measurements, have found strong indications of a double carbide corresponding to the formula Fe_3C-Cr_3C_2 and suggested that chromium up to a ratio of 4.3 to 1 is combined with carbon to form this carbide. While this composition ratio seems to hold for the 1 per cent carbon steels, it appears from this series of steels that a variation upward, with an increase in chromium and downward with an increase in carbon takes place. The peculiar behavior of the iron-chromium system, from the data available, suggests a constitutional change in the ternary diagram, (for steels containing less than 15 per cent chromium) along a smooth line corresponding to the Acm or S E line of the binary, iron-carbon diagram. Data presented by Monypenny* and Daeves*, support this view. Interruptions in this line, corresponding to the formation of distinctive carbides, in the range between it and Ac_1, are, however, quite probable. In fact, the degree of resistance to etching of the carbide particles increases as the chromium to carbon ratio increases. An etching test has been used by Murakami to classify some of the carbides he proposes. Similar experiments, repeated on the chromium group of steels listed above, have not yielded convincing results.

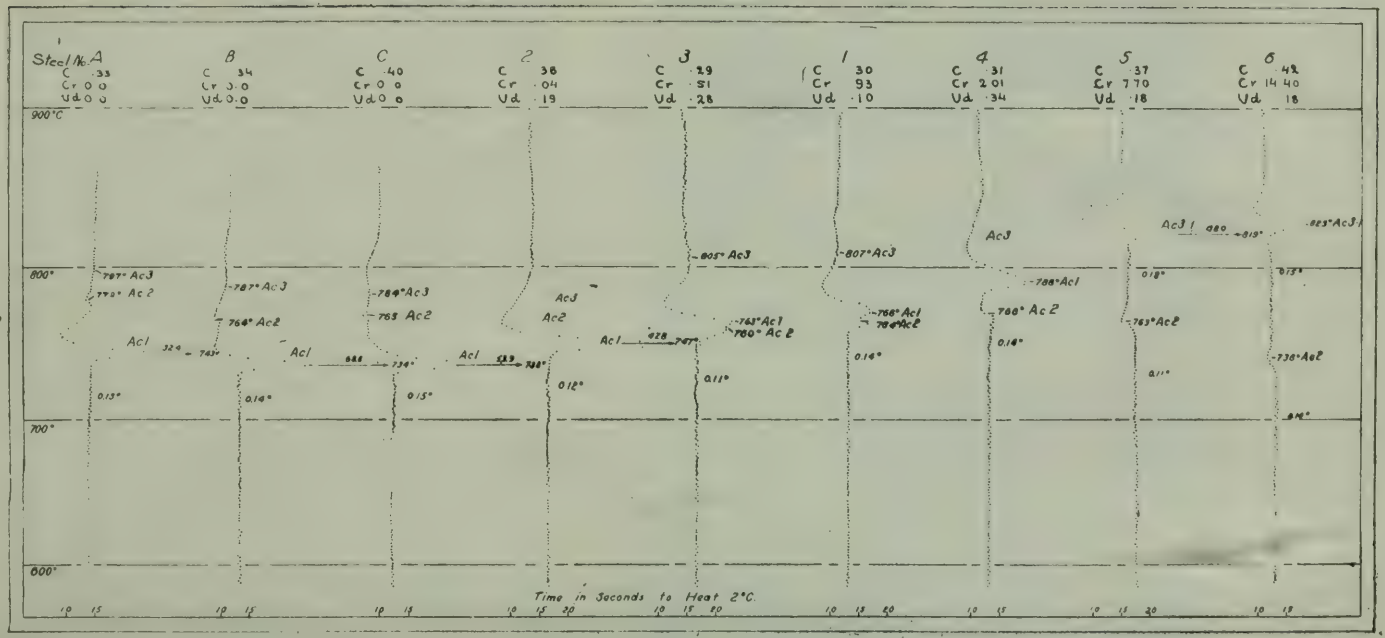
Since the quantity of carbide involved in the changes in these steels, is small, direct thermal evidence of a heat absorption or evolution corresponding to the dissociation or formation of the carbides is lacking. Evidence of the effect of chromium on the rate at which the transformations proceed, will be subsequently described.

Transformations During Cooling

The influence of chromium on the transformations during cooling, is shown in the curves of Fig. 7. A gradual lowering of the Ar_3 transformation is evident in the low chromium range. The retarding action of the dissolved and dispersed chromium and carbon on the Ar_3 change is apparent.

The Ar_1 change is but slightly affected. The position of this change

*Ibid.



CHROMIUM GROUP Ac THERMAL TRANSFORMATIONS

Fig. 6 shows the influence of chromium upon the transformations upon heating. It will be noted that the addition of chromium to a carbon-vanadium steel raises the critical points to the degree suggesting the cumulative action of the two alloying elements.

is graphically presented in Fig. 8. The increased stability of the chromium carbides appears in the gradual rise in Ac_1, which, if projected, meets Ac_3 at a point approximating a composition of 3.1 per cent chromium. The projection of the position of the Ar points results in an intersection at 2.65 per cent chromium. The field between which the A-1 and A-3 points combine, apparently represents a region which covers a critical point in the constitution and treatment of the steel. For the hypothetical zero rate of heating and cooling, the intersection would probably occur at about 3 per cent chromium, which would result in a chromium to carbon ratio closely corresponding to the 10:1 ratio tentatively proposed by Edwards* for the corresponding carbide, Cr_5C_2. For steels containing .30 to .40 per cent of carbon, this intersection marks the maximum amount of chromium and carbon that may be dissolved and completely reprecipitated when the cooling rate and initial temperature designated, are a maximum. Exceeding this initial temperature, rate of cooling or chromium content produces a super cooling which results in the unstable (hardened) state, indicated by the split transformation.

An increase in chromium from 2.0 to 7.7 per cent produces an increased resistance to the normal transformations. As shown in the curves for steels 5 and 6 (Fig 7), the lowered or split transformation is obtained with this chromium increase. A further increase in chromium to 21 per cent reveals a faint, reversible, thermal disturbance, corresponding to the A-2 transformation and a feeble evolution of heat in the 350-170 degree Cent. range upon cooling, corresponding to the Ar" transformation.

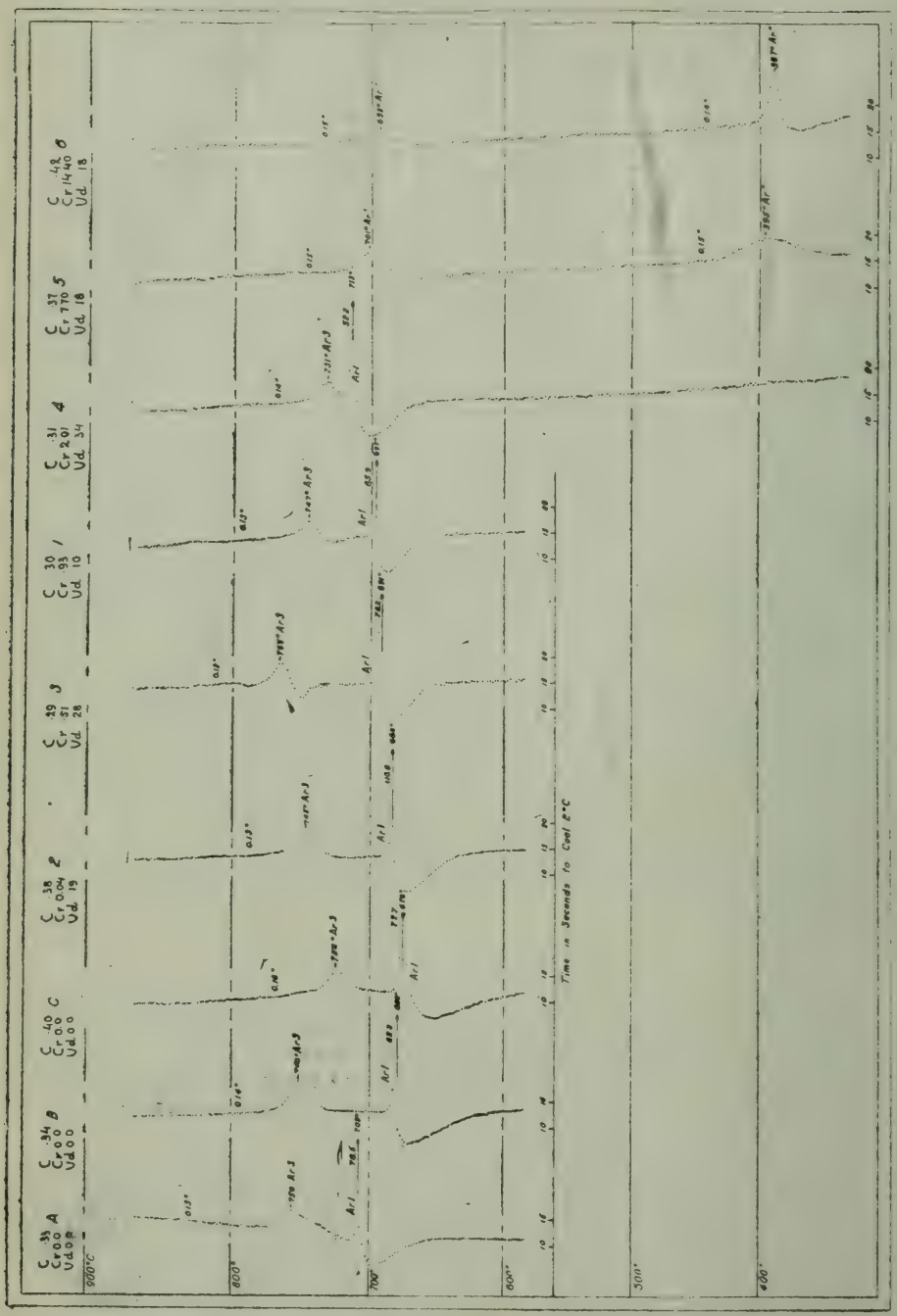
With the addition of chromium, the upper transformation (Ar') is gradually lowered then decreased in intensity as the lower transformation (Ar") becomes more intense, whence the latter passes through a maximum intensity as the upper transformation disappears. Finally a complete suppression of the lower transformation, is approached. This shift in the intensity of the transformations, with the addition of chromium is duplicated by increasing the rate of cooling, or approached in performance by cooling from successively higher temperatures above Ac_1.

Effect of Rate of Cooling

A change in cooling rates for steels 5 and 6 produces a lowering of both parts of the split transformation, with a complete suppression of the upper portion when a comparatively rapid rate is used. The thermal effect is analogous to cooling from higher initial temperatures, or increasing the chromium content. Table IV abstracts the data from some of the curves which were obtained.

The comparatively rapid drop in the position of Ar" in changing the rate from .12 to .16 degrees Cent. is illustrative of the sensitivity of these steels to small changes in the cooling rate. Significant changes in structure and hardness which accompany these effects will be subsequently mentioned. The occurrence of Ar" at a higher temperature in the high chromium steel was probably due to the incomplete solution of the carbides at the temperature from which cooling began; namely 977 degrees Cent.

*Ibid.



CHROMIUM CARBON Ar THERMAL TRANSFORMATIONS

Fig. 7.—This curve shows the influence of chromium on thermal transformations of several steels during cooling. A greater lowering of the Ar_3 transformation is evident in the low chromium range. A retarding action of the dissolved and dispersed chromium and carbon on the Ar_3 range is apparent. The compositions of the steels are shown on the chart.

Effect of Initial Temperature of Cooling

The effect of cooling from different initial temperatures upon the position of the transformation is shown in Figs. 9 to 13, inclusive. The results have been collected in Fig. 14.

In the low chromium steels, both Ar_3 and Ar_1 are lowered, when cooling is begun from successively higher temperatures. Of the two, Ar_3. is more rapidly displaced.

In the curves for steels 5 and 6, Ar″ is not directly detected in cooling from 850 and 900 degrees Cent. A lowering of the upper transformations and a decrease in their intensity implies their partial suppression and leads to the expectation of the occurrence of the suppressed portion in a lower inflection. Cooling from 975 and 1025 degrees Cent. produces a greater displacement upon cooling from the higher initial temperature.

Table IV

Effect of Rapid Cooling

Steel No.	Per Cent. Cr.	Rate—Degrees Cent. per sec.	Ar′	Ar″
5	7.7	.12	703	394
5	do	.15	701	395
5	do	.16	693	351
5	do	.88	none	320
6	14.4	.15	681	363
6	do	1.10	none	337

In steels of this type, the split transformation observed with increasing initial temperatures has been regarded as being caused by the obstruction to the normal transformations, introduced by the dissociation of the carbides. Where the chromium to carbon ratio is very high, a generalization of the hypothesis proposed by Murakami; namely, that the "lowering of the transformations is produced by the dissociation of the carbides and the retarding action of free chromium," appears to most satisfactorily fit the available data. In view of the two sources of free chromium, namely that present in the iron-chromium solvent and that derived from the carbide solute, two views might be advanced to account for the high initial temperatures required; namely the resistance to dissociation of the chromium-carbide particle or the resistance to diffusion of the elements of the carbides in the iron-chromium solution. Until the composition of solute and solvent are better established, it seems best that the retarding action of free chromium irrespective of its source be emphasized as the predominating cause of the displaced or split transformations.

Convincing evidence of the specific composition of the carbides, is lacking, but the results in general agree in showing that a progressive solution of the carbides occurs as higher temperatures are used. Quenched specimens of steels which show the split transformation, reveal a perceptible decrease in the number or size of excess carbide particles, with increasing quenching temperatures.

For example, in steel No. 5, cooling from 850 and 900 degrees Cent. produced a slight lowering in the single, observed, transformation. An examination of the structure and hardness indicates a progressive solu-

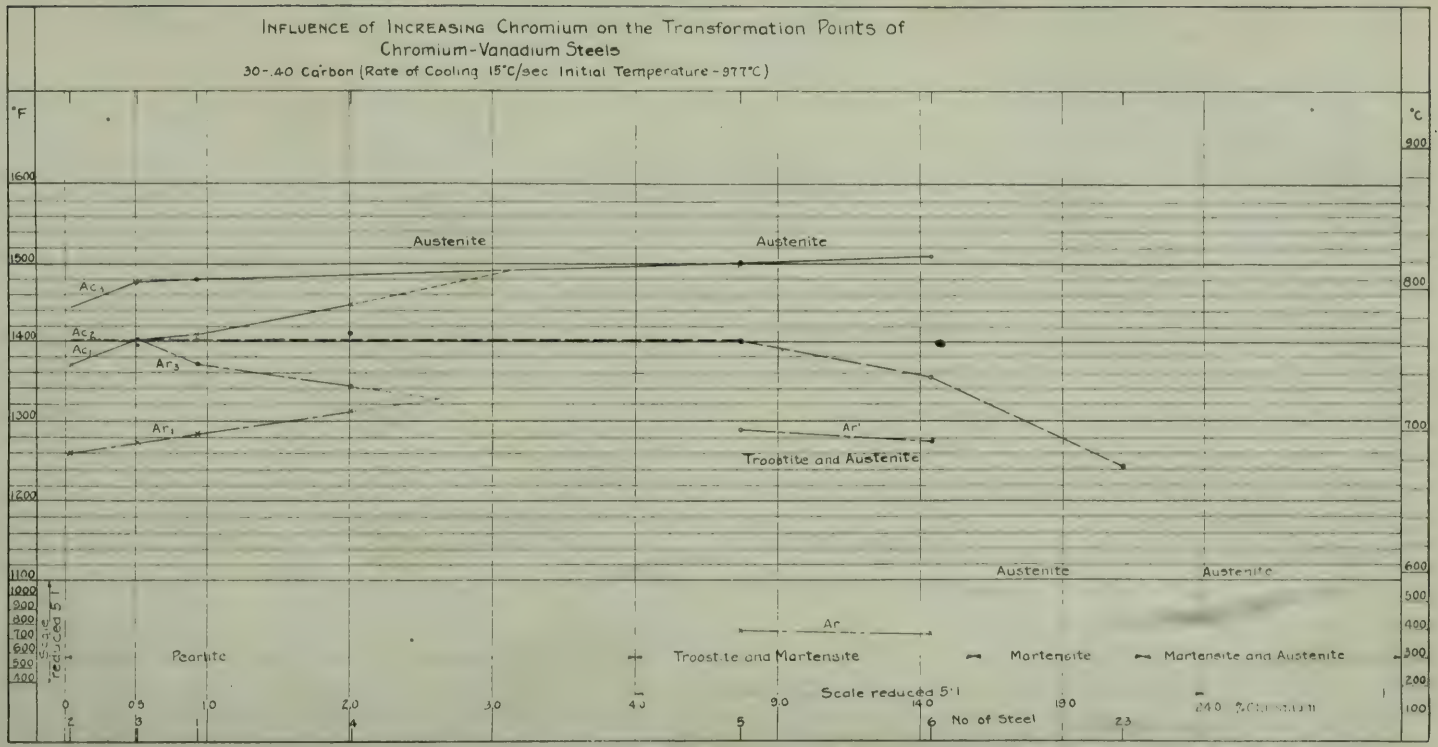
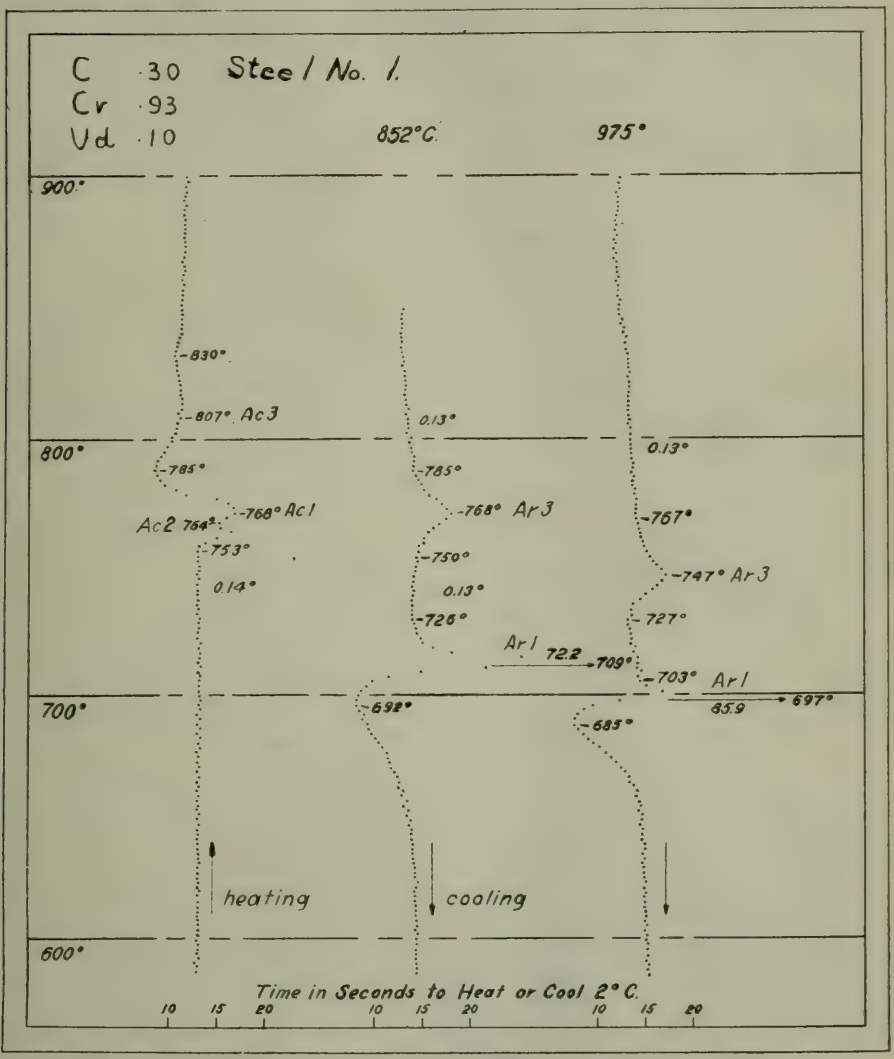


Fig. 8.—It will be noted that at the position representing the concentration of 0.75 per cent chromium the Ac_2 point which remains comparatively fixed on heating and cooling is joined by Ac_1 to form a single inflection. A change in composition would slightly shift the junction of the two transformations. Lowering the Ac_1 range with a slight increase in carbon and the effect of greater amounts of chromium in lowering the A-2 would be the result. The chromium appears to enter apparently in the carbide as marked by the Ac_1 rise leaving little evidence of the iron-chromium solution.

tion of the free carbides. Microscopically, the carbides in this steel disappear when a quenching temperature of 950 degrees Cent. is used. A cooling curve, from 977 degrees Cent. shows the split transformation

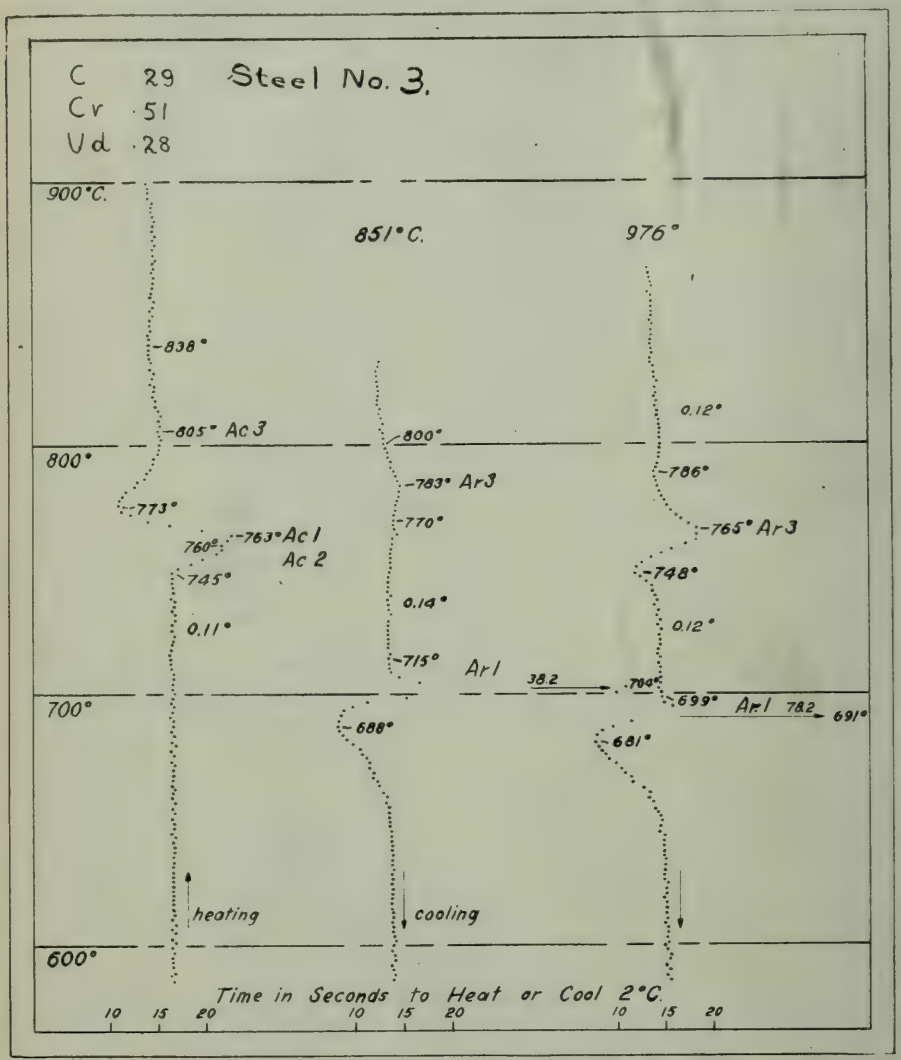


THE EFFECT OF HIGHER INITIAL TEMPERATURES

Fig. 9 shows the effect of higher initial temperatures upon the thermal-critical points both on heating and on cooling of the chromium-vanadium steel No. 1, which has the following composition: Carbon, 0.30 per cent; chromium, 0.93 per cent; vanadium, 0.10 per cent.

which might be associated with the disappearance of the carbides, except that cooling from a higher temperature produces an additional lowering. Changes in the intensities of the transformations are evident; the upper decreasing while the lower increases. This effect, increasing with rising initial temperatures, is apparently produced by the progressive dispension of chromium and carbon in the austenitic solution. Indeed the relation be-

tween the increased solubility and the distribution of the particles of the dispersion indicate a progressive course of division of the undissociated particles similar to the dispersion of Cu-Al_2, described by Jeffries (17)

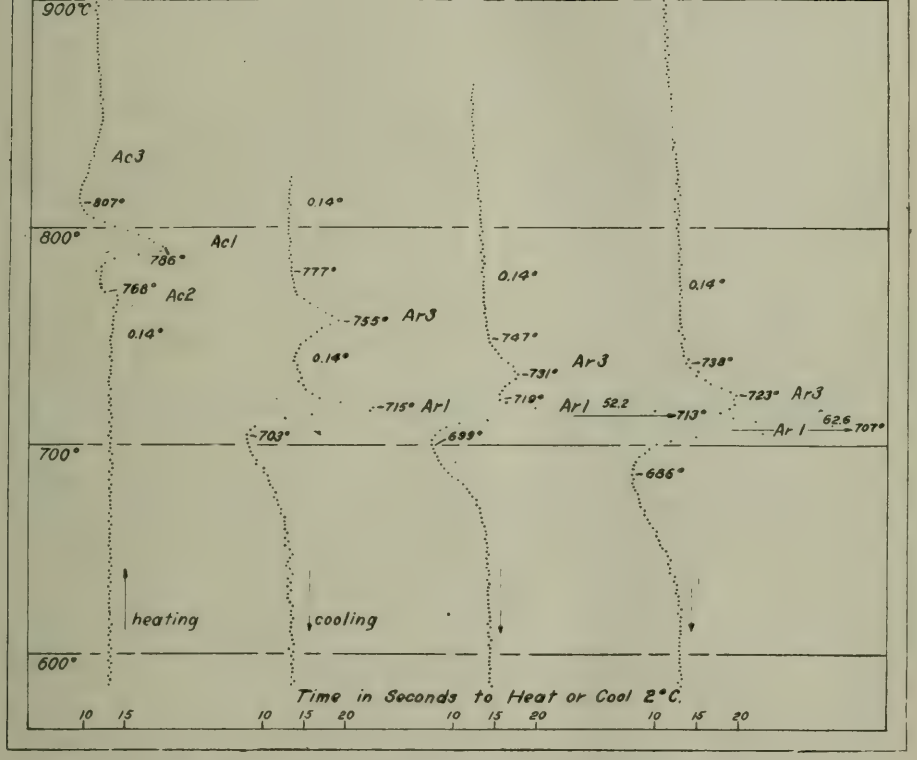


THE EFFECT OF HIGHER INITIAL TEMPERATURES

Fig. 10 shows the effect of higher initial temperatures upon the thermal-critical points both on heating and on cooling of the chromium-vanadium steel No. 3 which has the following composition: Carbon, 0.29 per cent; chromium, 0.51 per cent; vanadium, 0.28 per cent.

in copper-aluminum alloys. In view of the microscopically complete solution, existing at 950 degrees Cent. and the lack of any evidence indicating the presence of a carbide in molecular form, it seems certain that the state of division passes physically and chemically into submicroscopic and sub-molecular dimensions respectively. A maximum degree of dispersion would be approached when a temperature above 950 degrees

Cent. or prolonged heating at 950 degrees Cent. produced no appreciable change in the temperature position or magnitude of the transformations. This condition would correspond to a perfect solution or one in which the atoms of the solid solute and solvent were homogeneously distributed. In such a solid solution, the carbon atom which is most important in

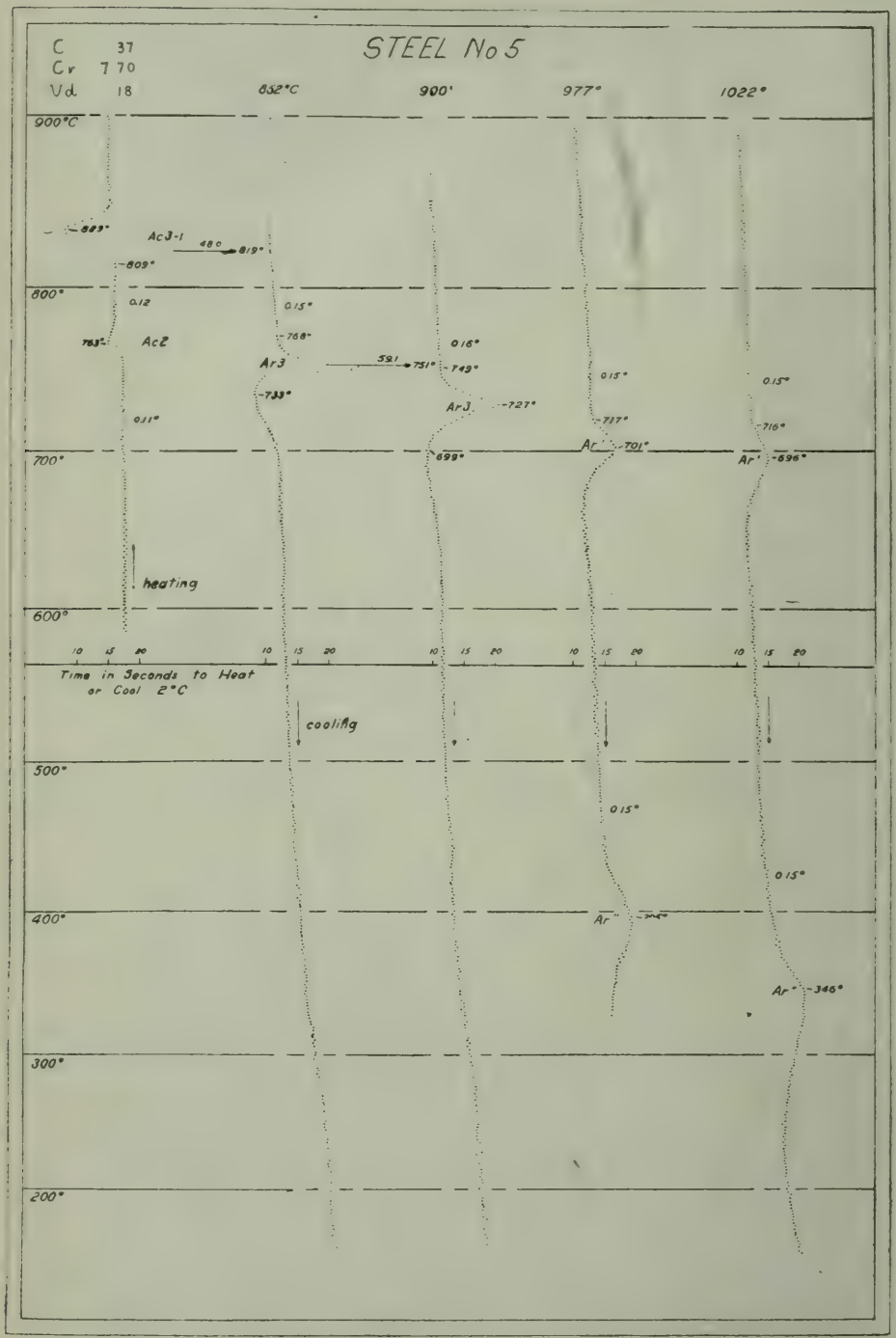


THE EFFECT OF HIGHER INITIAL TEMPERATURES

Fig. 11 shows the effect of higher initial temperatures upon the thermal-critical points, both on heating and on cooling of the chromium-vanadium steel No. 4 which has the following composition: Carbon, 0.31 per cent; chromium, 2.01 per cent; vanadium, 0.34 per cent.

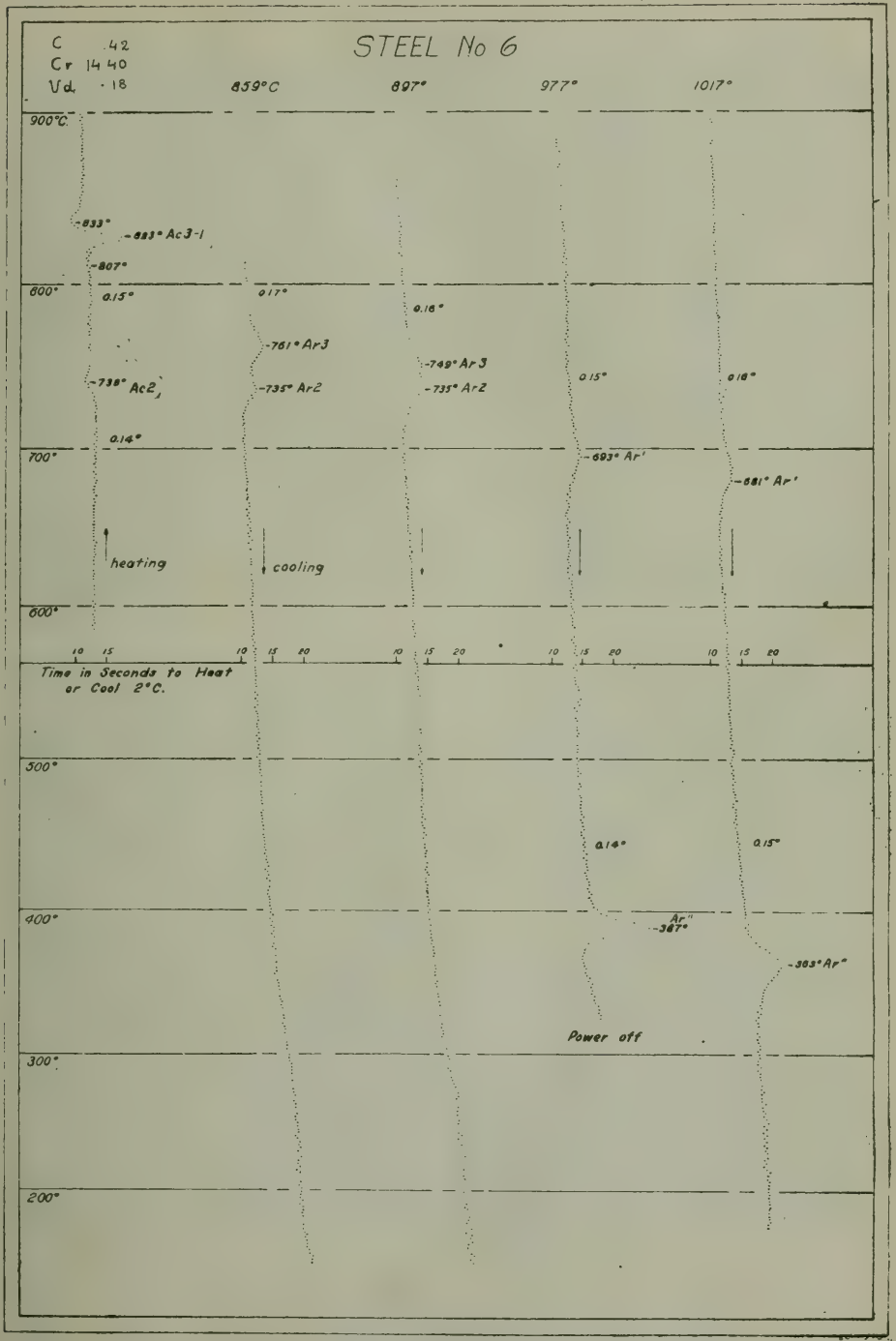
determining the character of the thermal transformations, would be lodged in an iron-chromium solvent. A small number of carbon atoms, as designated by a high chromium to carbon ratio, would require high initial temperatures or prolonged heating for their distribution. Conversely, a large number of carbon atoms would facilitate solution in heating or coalescence in cooling, and permit the use of lower initial temperatures and more rapid cooling rates. Throughout these changes, chromium in a highly dispersed form, or in solution, prevents a rapid reassociation of the compounds by retarding the rate of change from one form to the other.

The resistance of chromium to diffusion in iron, is well known. The difficulty in producing a homogeneous, chromium-iron solution, and



THE EFFECT OF HIGHER INITIAL TEMPERATURES

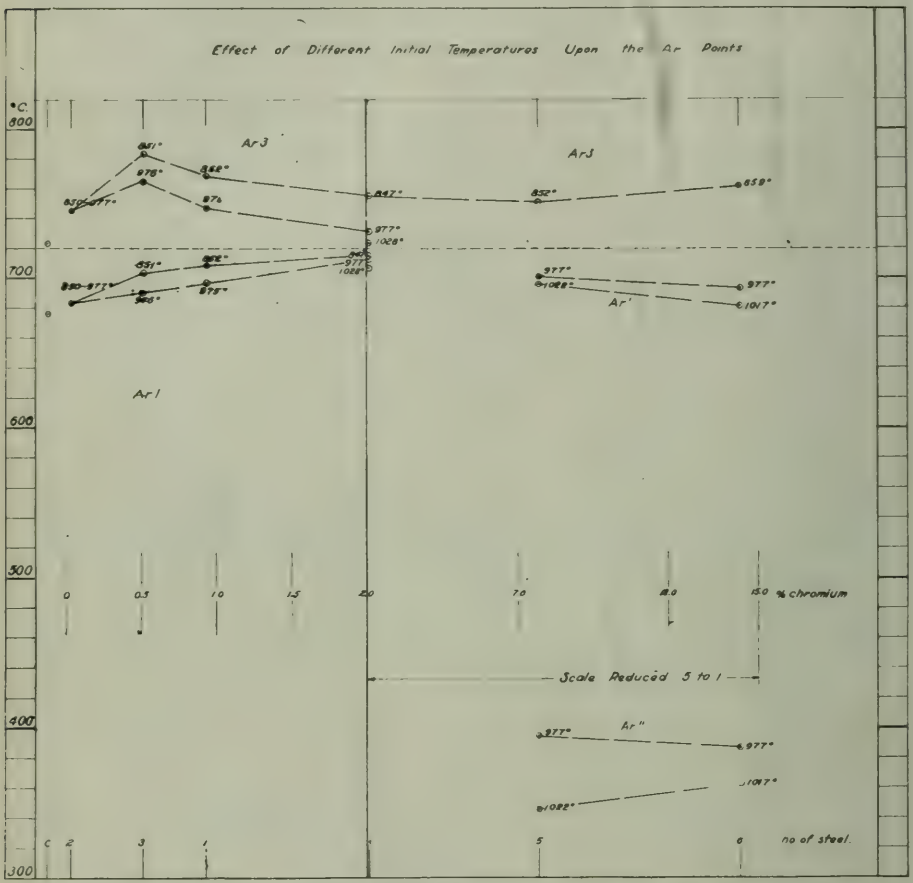
Fig. 12 shows the effect of higher initial temperatures upon the thermal-critical points both on heating and on cooling of the chromium-vanadium steel No. 5 which has the following composition: Carbon, 0.37 per cent; chromium, 14.40 per cent; vanadium, 0.18 per cent.



THE EFFECT OF HIGHER INITIAL TEMPERATURES

Fig. 13 shows the effect of higher initial temperatures upon the thermal-critical points both on heating and on cooling of the chromium-vanadium steel No. 6 which has the following composition: Carbon, 0.42 per cent; chromium, 14.40 per cent; vanadium, 0.18 per cent.

the occurrence of chromium segregates and dendritic growths in casts or rolled steels are frequently met. The difficulty of diffusing these segregated structures is ample evidence of the retarding action of chromium

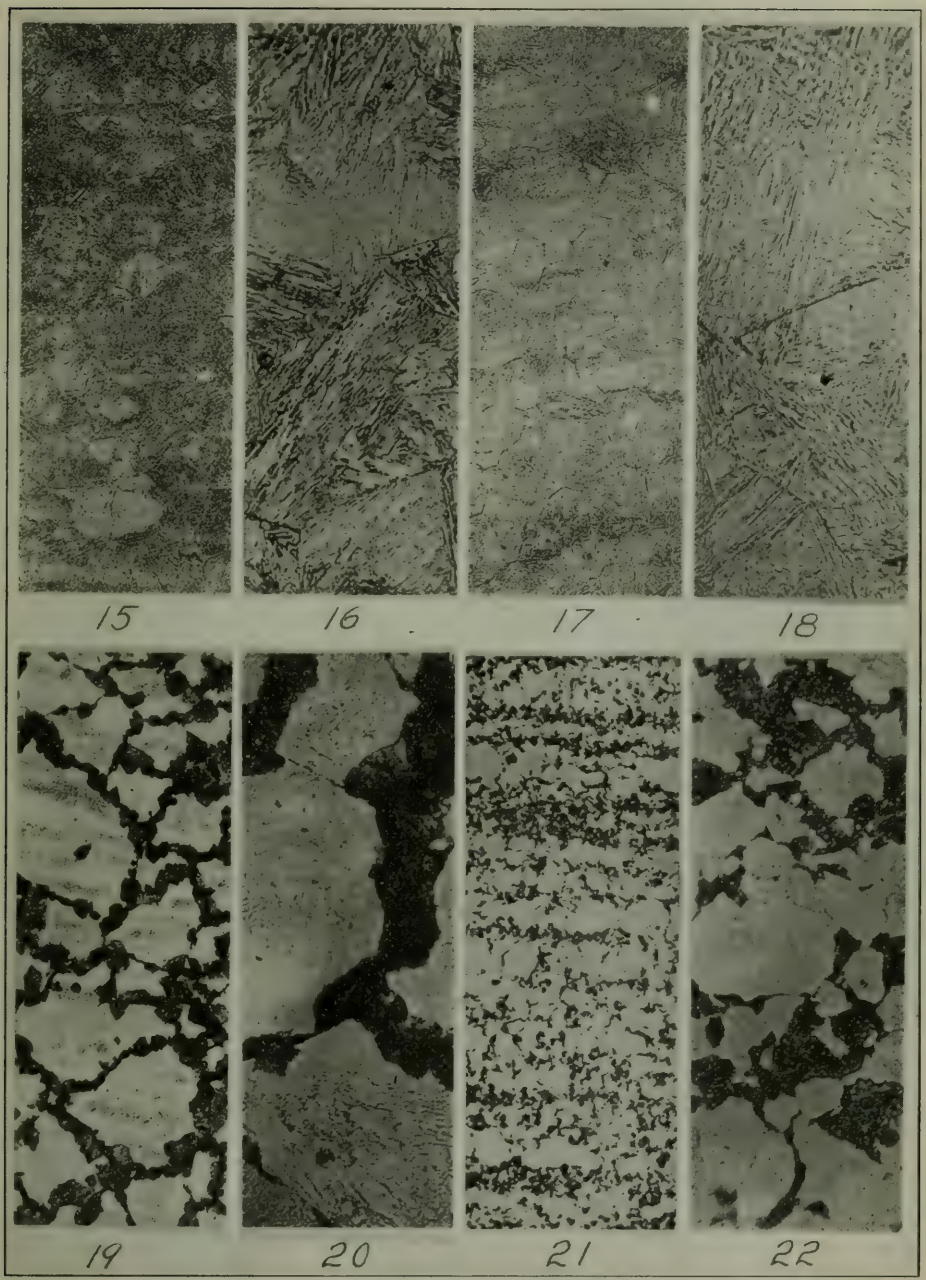


EFFECT OF VARYING INITIAL TEMPERATURES ON THE Ar POINTS
Fig. 14 shows the composite curve of the results shown in Figs. 9 to 13 inclusive.

on the rate at which internal changes progress. The reassociation of carbon atoms into molecular compounds would be correspondingly retarded. A lowering and splitting of the thermal transformations which mark the gamma to alpha change and the formation of carbide, would be expected.

Structure in Critical Ranges

The structure and hardness of the steels undergo important changes with the occurrence of the split transformation. The structures corresponding to various temperature positions in the curves for steels 5 and 6, are shown in Figs. 15 to 34 inclusive. In these steels, the lower or Ar'' transformation is not wholly suppressed by quenching from 1000 degrees



MICROSTRUCTURES

Figs. 15 to 22 show the photomicrographs of the chromium-vanadium steel having the composition: Carbon, 0.33 per cent; chromium, 7.7 per cent; vanadium, 0.18 per cent. All specimens were heated to 1000 degrees Cent. Figs. 15 and 16 were quenched; Figs. 17 and 18 were cooled to 700 degrees Cent. and quenched; Figs. 19 and 20 were cooled to 500 degrees Cent. and quenched; Figs. 21 and 22 were cooled to 350 degrees Cent. and quenched; Figs. 16, 18, 20 and 22, x 500. Figs. 15, 17, 19 and 21, x 100.

Cent. Consequently the structures are martensitic although markings characteristic of austenite are not completely removed. (Figs 15, 16, 25 and 26).

Specimens cooled from 1000 degrees Cent. to a temperature above Ar′ and quenched, retain their martensitic character, but the high chromium steel reveals a precipitation of carbide globules and an apparent diminution in the size of the grains. The grain size change is no doubt, due to the obstructing influence of undissolved and re-precipitated carbides. This evidence of the solution and precipitation of excess carbides in the gamma iron range, does not appear directly in the thermal curves, but is revealed in the thermal effects produced by cooling from successively higher temperatures. Confirmation of the solution is supplied in the increasing hardness with rising quenching temperatures, and the lowering of the transformations as previously mentioned.

Cooling within the range of Ar′, results in the structure shown in Fig. 33. Faint traces of the formation of troostite appear. Below the Ar′ inflection, troostite appears in its characteristic mesh-form occurrence, as shown in Figs. 19, 20, 29 and 30. In steels which show a split transformation, this effect indicates that the changes to alpha iron and carbide (Ar_1) is participating in producing the transformation.

An insight into the nature of Ar″ is partly revealed in specimens quenched at a temperature lying within the range of this transformation. Figs. 21, 22, 31 and 32 show little evidence of a change in the matrix, but within the troostitic areas, a coarsening of the emulsified carbides into the bright specks of Figs. 21 and 22 and the coarsened strings of Figs. 31 and 32 are unmistakable evidence of the coalescence of the troostic components within this temperature range.

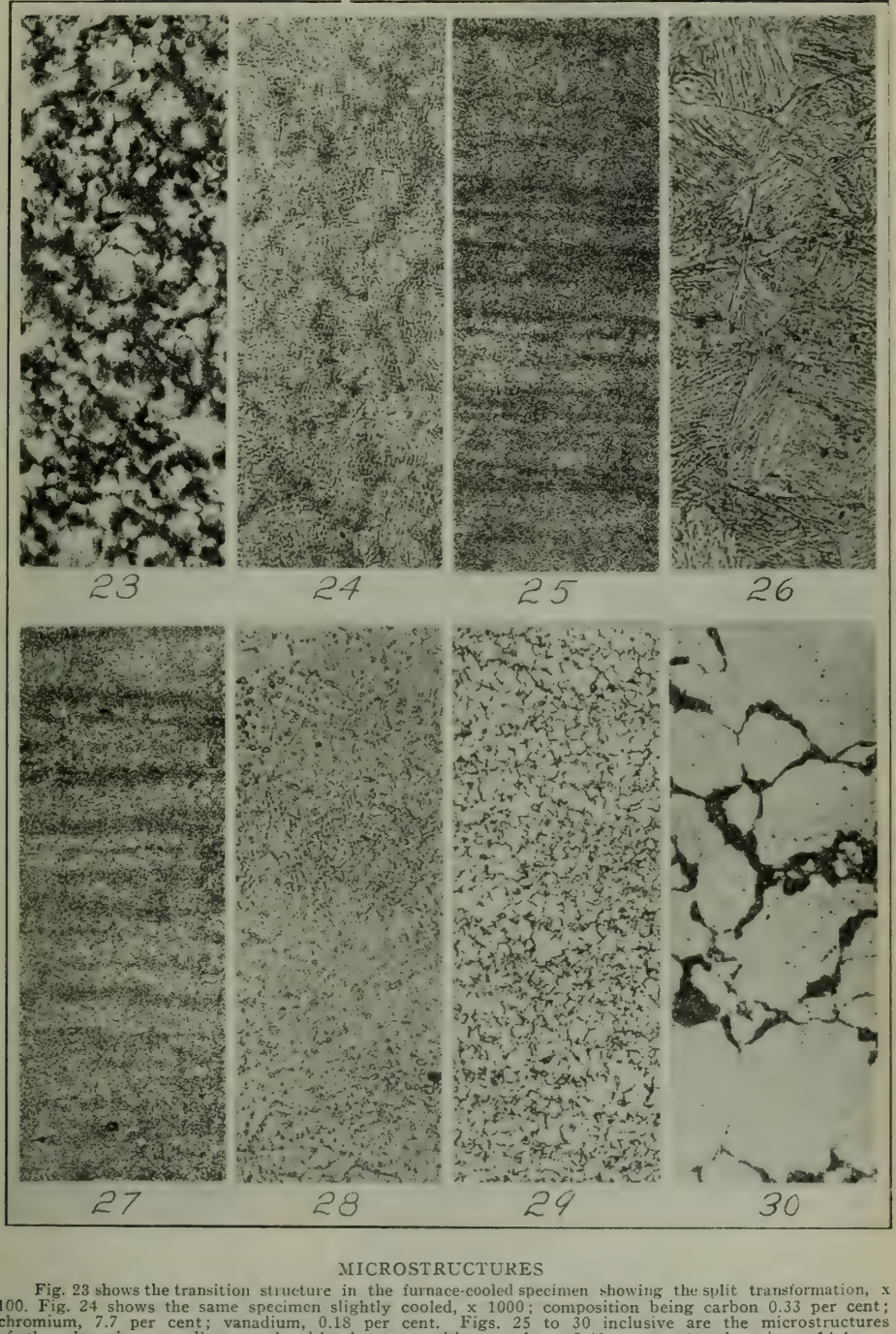
Very slow cooling produces the structures shown in Figs. 24 and 34 which are typical of these usually found in commercial annealed steels of equivalent composition.

The fact that the split transformation is a manifestation of an unstable equilibrium in a super-cooled or super-saturated solution, is sufficient to demonstrate that the structure of any particular specimen is dependent upon the precise condition under which that structure is produced. With this in mind, the structural limits indicated in Fig. 8 have been prepared for the conditions applied. The changes in structural constitution, which would be expected with increasing chromium, are indicated.

Relation of Lowered to Normal Transformations

The split transformations occurring in the above steels, have been recognized by French investigators (namely, Dejean, Portevin, Chevenard) as eruptive to manifestations of the suppressed normal transformations. Opinions as to the exact nature of the split transformation differ. Many of the French metallurgists who have been foremost in the study of this phenomenon, incline to the view that Ar″ is Ar_{3-2} suppressed. Another view held, and recently presented by Honda (19) is that Ar″ is merely Ar′ (Ar_1) suppressed. Difficulties in establishing either view, lie in the inter-dependence of A-1 on A-3.

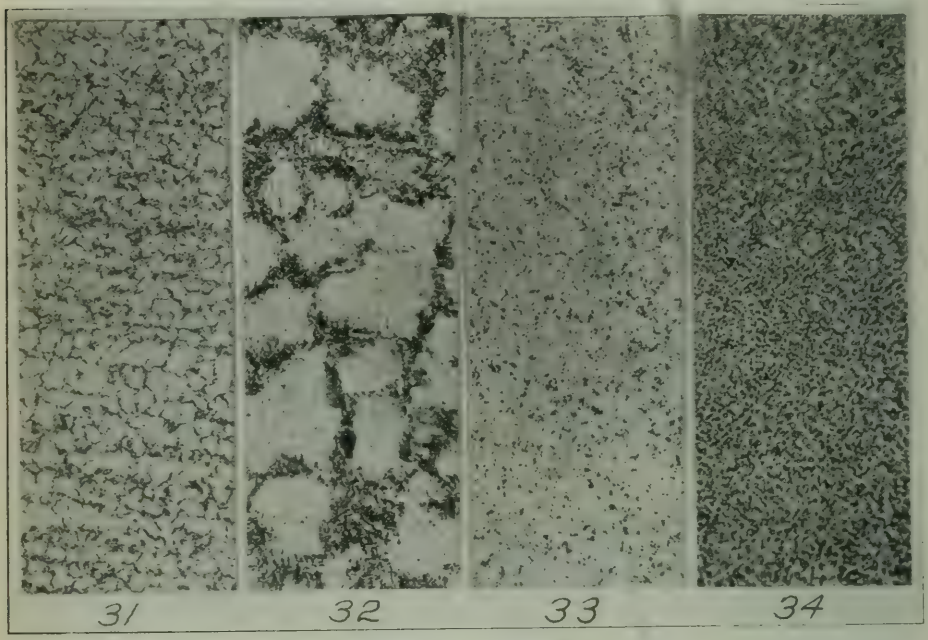
The fact that martensite (18), under suitable conditions, may be obtained as the sole product in a steel in which only the lower trans-



MICROSTRUCTURES

Fig. 23 shows the transition structure in the furnace-cooled specimen showing the split transformation, x 100. Fig. 24 shows the same specimen slightly cooled, x 1000; composition being carbon 0.33 per cent; chromium, 7.7 per cent; vanadium, 0.18 per cent. Figs. 25 to 30 inclusive are the microstructures of the chromium-vanadium steel with the composition, carbon, 0.42 per cent; chromium, 14.4 per cent; vanadium, 0.18 per cent, heated to 1000 degrees Cent. Specimens 25 and 26, x 100 and x 500, were quenched. Figs. 27 and 28, x 100 and x 500, were cooled to 750 degrees Cent. and quenched. Figs. 29 and 30, x 100 and x 500, were heated to 500 degrees Cent. and quenched.

formation occurs, is a strong argument favoring the opinion that Ar″ is the depressed expression of Ar_3-$_2$. Again, for steels which are partially austenitic, the same change is operative. In such steels, the upper transformation Ar′ of the split transformation, is suppressed and the



MICROSTRUCTURES

Figs. 31 and 32, x 100 and x 500, show the microstructure of the chromium-vanadium steel of the following composition: Carbon, 0.42 per cent; chromium, 14.4 per cent; vanadium, 0.18 per cent, heated to 1000 degrees Cent., cooled to 350 degrees Cent. and quenched. Fig. 33, x 100, shows the microstructure of the same steel heated to 1000 degrees Cent., cooled slightly below 750 degrees Cent. and quenched. Incipient troostite shown. Fig. 34, x 500, shows the microstructure of the same specimen after heating to 1000 degrees Cent. and slightly cooled.

degree of austenitization is dependent upon the efficacy of the suppression of Ar_3-$_2$, which is revealed in the magnitude of the Ar′ transformation.

A condition could obtain, in which the heat absorption at Ac_2-$_3$, equalled the heat evolution at Ar″, and the resulting structure appeared entirely martensitic. Obviously, this condition corresponds to that of maximum hardness.

When the conditions are such as to permit the magnitude of the heat evolution at the Ar″ transformation to exceed the heat absorption at Ac_3-$_2$, a structure composed of martensite and its decomposition products would be expected. The magnitude of Ar″ would indicate that Ar_3-$_2$ was accompanied by a portion of Ar_1, in the transformation. Again the occurrence of the split transformation as marked by a distinct upper and lower inflection of the cooling curves, at approximately 700 and 350 degrees Cent. respectively, is accompanied by the formation of a composite structure in which troostite is invariably one of the components. The persistent association of troostite with this phenomenon shows the inter-relation of A-1 and A-3 in such steels. Fig. 23, repre-

senting a corresponding structure, shows the dark troostitic spots blending into the brighter martensitic areas which still retain austenitic features. Since troostite consists of an emulsion of carbide in alpha iron, it is evident that a portion of the gamma to alpha change, (Ar_3) had been spontaneously followed by the Ar_1 change, giving rise to the troostite patches. If the slow change from austenite to martensite accompanying the heat evolution at Ar″ be accepted as the displaced form of Ar_{3-2} when the upper portion Ar″ is suppressed, then Ar_{3-2} would be expected to reappear in the austenitic areas when Ar′ does occur. Figs. 31 and 32 however, shows a precipitation and coalescence of carbides at Ar″ which show that Ar_2 proceeds toward completion at the Ar″ temperature. The obvious conclusion is that Ar_{3-2} and Ar_1 participate jointly in the transformation at Ar″. The structure gradient from troostite toward austenite which is associated with specimens which show the upper and lower transformation, marks the heterogeneous course of the combined, normal, transformation. Fig. 23 described above, is an excellent example of the heterogeneous course of the combined transformations.

Summary

1. The effect upon the thermal transformations of varying the carbon, vanadium and chromium contents of a typical chrome-vanadium steel is described. A pivoting composition of 0.30 carbon, 1.0 chromium, 0.18 vanadium, had been used to build a series of steels, varying in carbon, vanadium and chromium up to 1.15, 0.60 and 21.0 per cent respectively.

2. The addition of carbon to a chrome vanadium steel lowers the transformations upon heating but leaves them approximately 10-30 degrees Cent. above those for the corresponding alloy-free, carbon steels. Thermal curves indicate that the solution of the alloying elements is practically complete at 850 degrees Cent.; but a slight lowering of the transformations upon heating to 975 degrees Cent. indicates a further solution of dispersion above 850 degrees Cent.

3. The vanadium addition to the carbon-chromium steel, produces very small changes in the usual transformations. Ac_1 is slightly raised, passing Ac_2 at 0.18 per cent vanadium and continuing its rise at the rate of 1 degree Cent. for each 0.02 per cent of vanadium. Ac_3 is lost in the slow progressive heat absorption above Ac_1 that marks the diffusion of the dissociated carbides which were initially, a complex of iron, chromium and vanadium. A complete solution of the alloying elements occurs at a temperature between 850 and 900 degrees Cent. The addition of vanadium tends to lower Ar_{3-2} but Ar_1 remains constant up to 0.30 per cent vanadium.

4. The addition of chromium to the carbon-vanadium steel, slowly raises Ac_1, effecting a junction with Ac_2 at approximately 0.75 per cent chromium. The rise continues, meeting Ac_3 at approximately 3.0 per cent chromium and reaching a maximum at 7.7 per cent chromium. These two composition points occur in the neighborhood of similar critical points reported by Edwards and Murakami, respectively, who

interpreted them as composition limits for corresponding chromium carbides.

5. The pronounced lowering of A_2 when 7.7 per cent chromium has been exceeded, shows the participation of a large portion of the excess to form an iron-chromium solution.

6. The influence of vanadium is obscured in the high chromium concentrations.

7. In cooling, the split transformation occurs when 2.0 per cent chromium has been exceeded and becomes distinct when 7.7 per cent has been added. A further increase suppresses the upper and decreases the magnitude of the lower transformation until a 21 per cent chromium has been added, when but a faint indication of either is detectable.

8. More rapid cooling rates, lower and suppress the transformations as do successively higher, initial, temperatures. The former effect is similar to that produced by increasing the chromium content, and by analogy, is interpreted to show the retarding action of chromium in solution, upon the progress of the transformation. The lowering produced by successively higher initial temperatures appears to be due to the dissociation of the carbides and the dispersion of their component elements, in the iron-chromium solvent.

9. Structures indicate that Ar_{3-2} and Ar_1 proceed spontaneously in specimens which show two distinct (upper and lower) parts of the suppressed transformations. With a suitable composition, the normal transformation may be wholly or partially suppressed in the order Ar_1,Ar_{3-2} by increasing the cooling rate. The results produced are analogous to those obtained by manipulating the less flexible variable, chromium content, or to some degree, initial temperature.

In conclusion, the writers wish to acknowledge the assistance of the Misses Wymore, assistant chemist, and Preble, senior aid, Bureau of Standards, in checking some of the curves and determining the general character of certain experimental variables upon the final results.

Selected Bibliography

	Author	Title	Publication	Date	Volume	Page
(1)	Osmond, F.	Report on the Chromium Steels of R. Hadfield.	Journal Iron and Steel Inst..	1892	11	115
(2)	Scott & Freeman	Modified Rosenhain Furnace for Thermal Analysis.	B. S. Sci. Paper No. 348.....			
(3)	Hadfield, R. A.	Alloys of Iron and Chromium.	Journal Iron and Steel Inst..	1892	11	495
(4)	Griffiths, F. J.	The Role of Chrome-Vanadium.	A. S. T. M.....	1917	17	38
(5)	Moore, H.	The A-2 point in Chromium Steel.	Journal Iron and Steel Inst..	1910	1	268
(6)	McWilliam, A. Barnes, F. J.	Some Physical Properties of 2 Per Cent Chromium Steel.	Journal Iron and Steel Inst..	1910	1	246
(7)	Pultz, P.	Der Einfluss des Vanadiums auf Eisen und Stahl.	Metallurgie	1906	3	649
(8)	Norris, G. L.	The Role of Vanadium.	A. S. T. M.....	1917	17	22
(9)	Arnold, J. O.	Iron, Vanadium and Carbon.	Journal Iron and Steel Inst..	1912	1	215
(10)	Edwards, C. A. Greenwood, J. N. Kikawa, H.	Initial Temperature and Critical Cooling. Velocity of a Chromium Steel	Journal Iron and Steel Inst..	1916	XCIII	114
(11)	Edwards, C. A. Sutton, H. Oishi, G.	The Properties of Iron-Chromium-Carbon Steels.	Journal Iron and Steel Inst..	1920	CI	409
(12)	Edwards, C. A.	Function of Chromium in High Speed Steels.	Journal Iron and Steel Inst..	1908	II	433
(13)	Murakami, T.	Structure of Iron, Carbon, Chromium Alloys	Sci. Rep. Tch. Imp. Univ....	1918	7	217
(14)	Monypenny, J. H. G.	Structure of Some Chromium Steels.	Journal Iron and Steel Inst..	1920	CI	493
(15)	Daeves, K.	The Chromium, Iron, Carbon, System.	Zeit. Anorg. Chem.....	1921	118	55
(16)	Russell, T. F.	Constitution of Chromium Steels.	Journal Iron and Steel Inst..	1921	11	247
(17)	Jeffries, Z.	Slip Interference Theory of the Hardening of Metals.	Chem. and Met. Eng.....	1921	24	1057
(18)	Dejean, P.	Nature des Transformations qui se Pru Duisent pendant la Trempe des Aciers.	Revue de Metallurgie.....	1921	18	419
(19)	Honda, K. Kikuta, T.	On the Stepped A-1 Transformation in Carbon Steel During a Rapid Cooling.	Journal Iron and Steel Inst..	1922	Papers (May Meeting)	
(20)	Vanick, J. S.	Mechanical Properties of Some Chrome-Vanadium Steels.	Transactions—A.S.S.T	1922	11	196

SYMPOSIUM ON METALLURGICAL EDUCATION HELD AT THE FOURTH ANNUAL CONVENTION OF THE SOCIETY, DETROIT, OCTOBER, 1922

IN OPENING this meeting, the chairman, Prof. S. L. Goodale of the University of Pittsburgh, outlined briefly the purpose of the symposium. He stated that the symposium was arranged for the purpose of discussing "not how, but instead what to teach." Numerous written contributions had been received by the chairman in addition to those which were presented by their authors.

The first paper was read by the chairman, entitled

NOTES ON METALLURGICAL EDUCATION

By John A. Mathews

THE incident related in our TRANSACTIONS for September, 1922, in regard to the man who resigned because he "knew enough about steel treating to hold a job any place" is illustrative of a type of mind that is unfortunately not infrequent. This state of mind may result from lack of mental capacity, application, foresight and vision. It may be the result of early environment and lack of educational opportunities, and in many cases can be corrected by intimate association and contact with those possessing vision and enthusiasm for their work.

Presumably this state of mind exists more frequently among the hundreds of heat treaters outside the society than it does inside the society, and we can perform a genuine service for such men by bringing to their attention the opportunities for educational improvement and congenial companionship offered by membership in our organization.

The subject of this symposium, contemplated I assume, a wider view of education, and the part of it which I would emphasize is related to the laying of a foundation. The Good Book records the fallacy of building our house upon the sand. In modern days, the foundation is apt to be none too good because of the expense and poor workmanship. The same applies to the laying of the foundation for specialized education in metallurgy or any other branch of applied science.

The master builders of our great industries in the past generation for the most part were not college men. It is hardly right, however, to say they were "uneducated." Education is not always a matter of schooling, and the school of hard knocks has a brilliant body of alumni. Lack of schooling is not synonomous with lack of mental capacity, and with mental capacity men learn valuable lessons without the aid of books or teachers. While our great captains of industry have been in a narrow sense "uneducated," they have shown their mental capacity by their appreciation of educational training in others in a most practical fashion by their magnificent endowments of colleges and research institutions, and their recognition of the value of education is further evidenced by their selection of assistants and successors.

My own experience and observation lead me to believe that the present

A paper presented before the Detroit Convention Metallurgical Education Symposium, Oct. 3, 1922. The author, Dr. John A. Mathews is president of the Crucible Steel company of America.

tendency is toward too great specialization and beginning specialization upon an insufficient foundation. There is too much anxiety on the part of young men to take special courses of supposedly immediate application in the business of earning money. I believe implicitly in a liberal education as a foundation for professional studies, and as a teacher in a professional school I had an opportunity to compare the men who had such training and those who had not. I have watched some of these men since they graduated and so strongly do I feel the need of a sound foundation that I regret the tendency towards combination courses leading to two degrees in six years. Education in metallurgy, as in all branches of science, should afford the broadest possible training in the fundamental principles of science and economics. The lessons of history, and not the facts and dates of history, are of value. The principles of living and conduct may well be a part of professional education. We must develop the power of reasoning, of intense concentration and of straight line thinking. The mind of the student should be filled with a knowledge of usable principles of conduct, science and economics, and not with a heterogeneous collection of facts. Education should instill in the mind a passion for service, for constructive effort. The desire to serve is a more noble trait than the desire to get. Financial returns should be viewed as the return society makes for well directed creative effort, and not something that the recipient takes from the less fortunate. A broad foundation is necessary because very few students actually know in advance what line of business they will ultimately take up and experience shows that most of them change employment one or more times before getting established. Possibly if their preparation had been all that it should have been so many changes would not be made in the earlier years out of college. The various positions may be considered as post graduate coures in acquiring what was lacking at graduation. In the end, most men get into a place where they can "earn their salt," and if they stick, possibly a little more, until education plus experience bear full fruit. With education that confers a judicial mind, reasoning ability and sound thinking, along with clean living and passion for service, one becomes a powerful instrument for good.

The broad principles underlying metallurgical training are those afforded by a knowledge of chemistry, physics and mathematics, and during the study of these subjects one should acquire a thorough training in what is known as the "scientific method." Certain principles are common to all the sciences, yet each great division requires its own specialized facilities with which the student must be familiar. Improvements in methods of observation, either by new facilities or by new applications of old methods constitute a valuable contribution to knowledge. The invention or application of new and precise appliances aids in the appreciation of the significance of facts and phenomena which were previously obscure and leads us gradually into the deeper penetration of nature's secrets. Metallurgical education should be along lines which will stimulate diligence and accuracy of observation. As Sir William Turner has said "By their application, new facts are discovered and tabulated, their order of succession is ascertained, and a wider and more intimate knowledge of the processes of nature is acquired, but to decide on their true significance a well-balanced mind and the exercise of prolonged thought and reflection are needed. Scientific method consists, therefore, in close observation, frequently repeated so as to eliminate the possibility of erroneous seeing; in experience checked and controlled in every direction in which fallacies might arise; in continuous

reflection on the appearance and phenomena observed, and in logically reasoning out their meaning and the conclusions to be drawn from them. Were the method followed with integrity by all who are engaged in scientific investigation the time and labor expended in correcting errors committed by ourselves and by other observers and experimentalists would be saved and the volumes devoted annually to scientific literature would be materially diminished in size."

For the young man assuming a position, say in the heat treatment of steel, it is unimportant whether he knows the physical properties of the various S. A. E. steels from memory or not. It is unimportant whether he recalls the recalescence temperatures of 1 per cent carbon tool steel. It is vastly more important that he should know the physical and chemical principles underlying the successful practice of heat treatment, and as to the facts, his knowledge should consist, first, of knowing where to find them, and second, the methods for determining them for himself if they are not already recorded. I am convinced that there is a great waste of time and effort in merely duplicating work that has been done and recorded. To avoid this, a knowledge of the literature is important and the instruction in metallurgy should stimulate the interest of the student in regularly and systematically following the current literature as well as referring to the older literature and history of the subject. The processes by which our present knowledge of metallurgy has been acquired and the historic development of processes are of much importance.

In conclusion, I should like to paraphrase the words of Professor Freer written some twenty years ago in regard to the spirit of organic chemistry. What he said is equally true of metallurgy and in the quotation we will take the liberty of substituting that word for "organic chemistry." "No student of metallurgy can afford to neglect the historic side of the question. No one can claim to have absorbed its spirit unless he understands how the knowledge of the present has grown from the toil of the past, and none may expect to create for himself unless he understands the methods and views of his predecessors. In so doing, he must give his whole soul to the task before him. Science is a stern mistress who gives the best within her only to those who follow her unflinchingly, however difficult the task, and however remote the prospects of pecuniary gain or of self aggrandizement, their sole hope being that they too may add to mankind's knowledge of the truth that future generations may profit by the sacrifices of the present. This has been the spirit of the past. It must also be the spirit of the present and future. Science is moving onward swiftly, relentlessly and unflinchingly—no half hearted followers for her—they fall by the wayside. There is no place for those who have not patience to acquire the necessary knowledge. The strong press forward in fierce rivalry, each striving for the ultimate knowledge—a perfect human knowledge, by which from any given premises a logical conclusion may be drawn with unerring accuracy."

Following a few brief remarks by the chairman, H. B. Knowlton, instructor of metallography and heat treating at the Milwaukee Vocational School presented the following paper:

EDUCATION OF MACHINISTS AND TOOL MAKERS IN HEAT TREATING

By H. B. Knowlton

Abstract

Heat treaters, at the present time, are handicapped because of a lack of knowledge of iron and steel, and heat treatment, on the part of some designers, machinists and tool makers. It is suggested that the simplest remedy for this difficulty, is the compulsory education of apprentices of the tool making and machinist trades. During the past year, an apprentice course of this nature has been given in the Milwaukee Vocational School. This paper gives a description of the heat treating department and an outline of the courses. Some of the charts used in teaching the classifications of steel, their properties, uses, and methods of heat treatment, are shown. A brief discussion of the harmful effect of sharp internal angles, is also given. The aim of the course is to train machinists so that they will be able to work more intelligently with heat treaters. Already some of the students have left their trades and gone into the heat treating field. Night courses in heat treating and metallography, are briefly mentioned. Both of these courses are designed for the benefit of the non-technical man. This plan of education is submitted for the consideration of the Society.

AT THE meetings of this society we hear many papers dealing with the errors which may occur in the hardening room, and methods for their elimination. We hear of defects in the steel, pyrometer troubles, quenching media, furnace control, and proper methods for heat treating. It seems to the writer that one of the most common causes for trouble in the hardening room, usually receives too little attention. This is lack of knowledge of the fundamentals of steel and its heat treatment on the part of the designer and manufacturer of parts which are to be heat treated. While there are many designers, machinists, and tool makers, who are well informed on this subject, it is believed that an investigation would show that there are an alarming per cent who do not know the classifications of steel, their properties and uses; who do not understand the reasons for failure in service, nor appreciate the problems of the hardener. If this is a fair statement of the case, then we must admit that the hardener or heat treater is often not to blame for the failures that are charged against him.

Probably most of the members of this society who have worked directly in the hardening room could give many experiences where a lack of knowledge on the part of the designer or manufacturer greatly handicapped them. A typical example from the writer's experience is as follows: Five ball pein hammers were sent into the hardening room together. They looked exactly alike and as they were received from the same man at the same time it was the logical assumption that they were all made of the same material. The maker of these hammers gave us the usual definite information that the material was a good grade of tool steel. After being requested for definite information, he finally said that they were C-Extra. That was all that he could tell us and he thought that he had told the whole story. The five hammers were all given identically the same heat treatment.

After hardening and drawing, two of them were too soft and the other three were still so hard that it was feared that they might chip at the edge. Evidently they were not of the same material. After a thorough investigation we found that three hammers had been made from one bar and the other two from another bar in the same rack. By examining the labels on the bars in that rack it could be plainly seen that the rack contained C-Extra No. 2½, and C-Extra No. 4½. Evidently the hammers which came out the softest were of the lower temper, while the other three were of the 4½ temper, that is they were higher in carbon. On this assumption we hardened and tempered them all again. This time the hammers of the high temper were drawn much further than usual while the others were given only a light draw. The hammers were, of course, treated so as to leave the center much softer and tougher than the face and the pein. This time all of the hammers came out satisfactory. This is merely one example of how a lack of knowledge on the part of the manufacturer handicaps the hardener and how the hardener may vary his treatment and produce satisfactory results, even when the tool is not made of the most suitable steel, if he is only informed exactly what material is used. Undoubtedly you can think of many similar examples in his own experience.

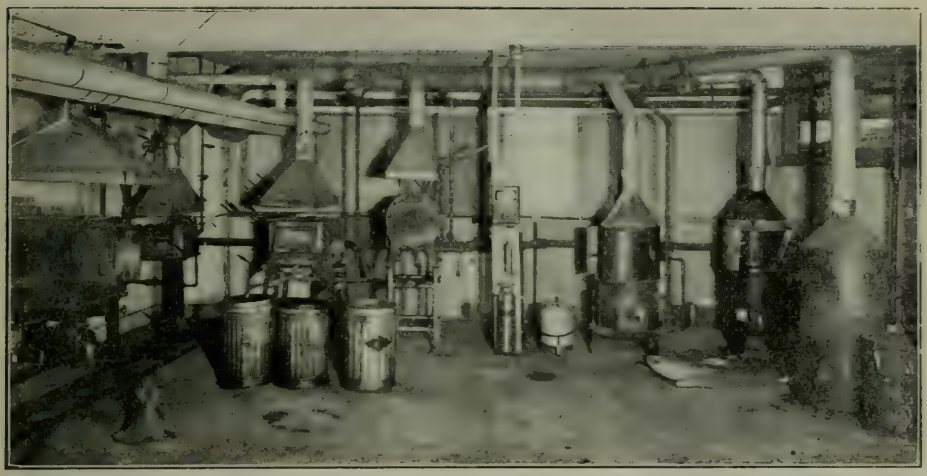
There are two possible remedies for this type of difficulty. First, to educate all machinists, tool makers and designers. Second, for the hardener to determine the composition of every piece which enters his department. This latter can be done accurately by chemical analysis, but this is, obviously, not usually feasible. Of other tests for determining composition, only the spark test on the emery wheel, is worthy of mention. In the hands of the expert this is indeed very valuable. It is doubtful, however, whether the average hardener can tell small variations in carbon content in this manner. Anyone can readily see the difference between very low carbon steel and tool steel.

The heat treater is also handicapped if the designer or manufacturer lacks knowledge of other points concerning steel and its heat treatment. For example, how often do we recive a tool for hardening which has sharp internal angles when it might have been designed with fillets. One old practical hardener said that if we could convert everyone to a "religion of fillets" that a large per cent of our troubles would be over. Does it not seem that one of the most crying needs of heat treaters today is education of everyone who designs or manufactures steel articles which require hardening or other heat treatment?

Granting that the problem of education is important, we have yet to decide upon the best method for teaching designers and manufacturers. It is believed that our Society is accomplishing a great deal along this line. Unfortunately, we can not compel all designers, machinists, and tool makers, to join the Society, attend its meetings and read the TRANSACTIONS. It is suggested that we should all do our utmost to interest them in the Society and our problems, but at best we will probably not reach all that we would like to. At the present time, too many do not appreciate the fact that they need any education. It seems to the writer that this problem like many other problems of education, will only be solved by reaching the coming generation. This is what we are attempting to do in Milwaukee by educating the apprentices.

Education of Apprentices

We believe that in Milwaukee we are pioneers in the idea of educating all apprentices to the machinist and tool making trades, in the subject of steel and its heat treatment. Metallurgy and the heat treatment of steel have been taught in colleges and universities for years, but the number reached by the colleges is unfortunately comparatively small. Also it must be considered that the average college student lacks practical experience in the shops, and is liable to be interested in the academic rather than the commercial phase of



One End of the Furnace Room of the Heat Treating Department of the Milwaukee Vocational School.

the subject. It was thought therefore, that it might be of interest to the members of the Society, to describe our work with the apprentices, giving an outline of our course, and stating some of our aims, and what we have accomplished thus far. We will then leave it to your judgment, whether or not our plan is worth while and whether it should be pushed in other places.

The Wisconsin apprentice law requires that all endentured apprentices shall attend a vocational school one half day per week. During this period they are taught mechanical drafting, shop mathematics, blue-print reading and other subjects related to their trades which they would not learn in a thorough manner in commercial shops. They are not taught the operation of machines or other phases of their trade which they are practicing every day in the shops. Thus the vocational school supplements the shop training, by teaching the subjects which the average shops are not in a position to give. The instructors in the vocational school are men who have had both academic education and shop experience. They differ from the shop foremen in that it is their sole business to teach, while the principal duty of the foremen is to keep after production. Teaching the apprentices is liable to be only incidental with the latter.

A year ago the Milwaukee vocational school started a course in steel and its heat treatment for the apprentices to the machinist and tool making trades. It was the original intention to make this compulsory, but up to the present time, this has not been necessary, as we have had a waiting list of those wishing to enter our laboratory sections.

Heat Treating Department of the Milwaukee Vocational School

Our heat treating department occupies three rooms; a lecture room equipped with a stereoptican; a furnace room containing various types of furnaces, a lead pot, cyanide pot, oil tempering furnace, quenching tanks, pyrometer system, etc; a metallographic laboratory equipped with a complete photomicrographic apparatus, polishing equipment, and dark room. Our testing equipment includes Brinell, scleroscope and drop testing machines.

Outline of Course

The course includes both lectures and laboratory work. The lectures are devoted to the manufacture, properties, and uses of wrought iron, and the various kinds of cast iron and steel. The lectures are illustrated with lantern slides. The purpose of these talks is not to give the student a working knowledge of the processes of manufacture, but to teach him what the different materials are and what they should be used for.

The laboratory work covers the following subjects:—the Metcalf test showing the effect of various hardening and annealing temperatures on the grain size and hardness and toughness of plain carbon tool steel; hardening tool steel by the eye to produce the maximum grain refinement; the control and maintenance of furnaces, the construction, use and maintenance of pyrometers; the use of the scleroscope and Brinell machines; the tempering of hardened steel both by color and in oil and other liquid baths; thermo-critical points, methods of determination, importance, and commercial application; effect of expansion and contraction on passing through the critical range; the classification of plain carbon tool steels, their properties and uses; hardening and tempering various commercial tools of plain carbon steel; different methods of annealing; high-speed tool steel, properties and uses, annealing hardening and tempering; air hardening tool steel; fast finishing tool steel; heat resisting and hot die steels; non-shrinking tool steels; other alloy tool steels; the spark test for determining the classification of steel; the effects of oil, water, and air quenching on different steels; the heat treatment of the medium carbon steels; alloy steels of medium carbon; case hardening; the effects of sharp angles; warping and cracking, causes and cures.

It should not be inferred from the above outline that these subjects are taught in the exact order in which they are here stated. Some of the points which are mentioned only once in the outline are brought out over and over in the actual laboratory works as we believe that the only successful method of teaching involves frequent repetition. It is obviously impossible in this short paper to describe in detail how all of these points are taught, but it may be of interest to tell how a few of them are brought out.

Effect of Sharp Internal Angles

Every steel treater knows that square shoulders, counter bored holes, V cuts and sharp internal angles constitute a weakness, but many machinists and tool makers seem to fail to appreciate this point. For this reason we lay great stress upon it. The students are shown samples of commercial failures. In addition they perform the following experiment: A bar of ¼-inch x 1 inch, 1.20 per cent carbon annealed tool steel is bent cold through 180

GENERAL CLASSIFICATION OF STEEL

Carbon Per Cent	Common Names		Properties	General Uses	METHODS OF MANUFACTURE							
					Bessemer		Open Hearth		Electric		Crucible	
					Plain Carbon	Alloy	Plain Carbon	Alloy	Plain Carbon	Alloy	Plain Carbon	Alloy
.00- .05	Very low carb. Dead soft very mild	Ingot iron	Very soft & tough	Rivets—Forging stock	Chea forgings Castings, machine parts Building construction	NOT USUALLY MADE	Rivets-Bridges Cars Locomotives-Autos Boilers - case hardening	Special Alloys—Other Alloys Similar to Plain Carbon Steels—Effect of Alloy	Same as	Special Alloys—Low Alloys Similar to Corresponding Carbon Steels—Effect of Alloy	NOT USUALLY MADE	Many Special Alloys Not Given in This Chart
.05- .15		Screw stock hot rolled	Forges cold or hot T.S. 45000	Forgings and castings-structural steel for bldgs., bridges, cars and Locomotives-flange steel-bars for machined parts-case hardening								
.15- .25	Low carbon mild-soft	Cold rolled mach. steel							Corresponding			
.25- .35				Parts require slightly greater strength than obtainable with .20% steel								
.35- .45	Medium carbon half hard		Strong & tough some hard'g pw T.S. 85000 An.	Forgings, castings, and machined parts requiring considerable Strength and toughness	A Rails B C		Shafts-Gears axles-forgings - castings bars-rails		Bessemer And Open Hearth			
.45- .55	Oil treating		T.S. 100000 HT						but better			
.55- .65				Heavy R.R. rails-solid wrought wheels-tires-parts requiring Toughness and resistance to wear			Heavy rails		Quality			
.65- .75					NOT USUALLY MADE		wheels tires					
.75- .85			Will harden- will stand ham'r'g	Smiths' tools, hammers, dies, and tools requiring some hardness and great toughness								
.85 .95	High carbon						Lowest Quality Tools		Tools perhaps		Best Grades of Tools	
.95-1.05	Hard		Willaeq. greater hardness but less toughness	Tools requiring greater hardness and some toughness axes, chisels, taps, etc.					equal to			
1.05-1.15	Tool Steel								Crucible			
1.15-1.25			Hard cutting edge	Tools requiring hard cutting edges but not much toughness					Steel			
1.25-1.35	Very high carbon		Will become very hard but brittle	Very hard tools-lathe and slotter.					Tools			
1.35-1.45	Very hard			Very hard tools not requiring toughness								

GENERAL PROPERTIES DUE TO METHOD OF MANUFACTURE

Chemical Analysis	S .10% Max. P .10% Max.	S .05 Max. P .045 Max.	S .02 Max. P .01 Max.	S .01 Max. P .01 Max.
	Does not weld as well as wrought iron. Not recommended for heat treating. Not as clean or sound as other kinds of steel.	Cleaner and sounder than bessemer	Best and purest grades of steel	

NOTE:

It is the intent of this chart to give only a general idea of the classification of steel. It is impracticable to show all possible kinds of steel on one chart. It is also impossible to draw sharp lines between the classes. Tool steels and special alloy steels are given on other charts. A. S. T. M. and S. A. E. give specifications for construction steels.

degrees without cracking or breaking. The same bar is then nicked with 6 strokes of a hand hack saw and then broken with one or two blows of the sledge. It may be noted that the nick is so small that it can hardly be seen and yet it so weakens the bar that it breaks with very little bending. We find that this simple experiment makes quite an impression upon the students.

Classification of Steel

We also lay great stress upon the classifications of steel and the importance of using the right steel for the job and especially the importance of telling the heat treater just exactly what steel was used. Figs. 4-7 show our blue prints giving the classifications. We try to impress upon the student that the grade or quality of a plain carbon tool steel has nothing to do with the carbon content, and that the carbon content does not tell the price or quality. We call their attention to how the tool steel companies mark their bars, and explain the meaning of the temper numbers. The student is taught that the buyer must co-operate with the steel maker and tell him what the steel is to be used for when purchasing material.

The charts shown herein are only a few of many charts which we employ. The S. A. E. charts, Prof. Keller's charts, critical range diagrams, curves show proper speed of heating, and many other curves and diagrams are also used.

General Aim of the Course

All through our work with the apprentices, we bear in mind that primarily we are training embryo-machinists and tool makers rather than heat treaters. We hope that our boys, as a result of this training, will work more intelligently with heat treaters than some machinists and tool makers do at the present time. Furthermore if any of our graduates do leave their trades and enter the heat treating field, we believe give them a foundation to build upon. If we accomplish this much, we believe that we have contributed something valuable toward the advancement of heat treating.

Other Courses

Besides the course for apprentices, our department gives two more advanced evening courses. The first of these is a course in heat treating, which is intended primarily for men who have had practical experience in the shops. This class meets two evenings per week during the first half of the school year. During the last half of the year, there is given a course in elementary metallography of iron and steel. While there are always a few college graduates in this class, we attempt to give the work in such a simple fashion that it will be entirely within the group of the non-technical man. The main object of this course is to give the practical man the elementary principles of metallography and a reading knowledge of photomicrographs so that he will get more out of the lectures given at the local meetings of the American Society for Steel Treating, and be able to read more easily the articles in the TRANSACTIONS and other technical publications.

Results

As our apprentice classes have only been in operation one year, it is rather early to begin counting the results. However, it may be said that the boys take a very decided interest in the work. Although it was not our

TOOL STEELS

	High Speed	Air Hardening	Fast Finishing	Hot Die Heat Resisting	Non Shrink Oil Hardening	Plain Carbon
Composition	16-18% Tungsten, 3-4% Chromium, 0.5-1.0% Vanadium. Some brands contain Cobalt: some contain higher Vanadium and lower Tungsten	About 10-12% Tungsten	Low Tungsten, High Carbon	Usually low Tungsten, sometimes Chromium and Vanadium	Usually contains about 1.5% Manganese: sometimes other Alloys	
Properties	Retains hardness and cutting edge when run at a high speed with edge of the tool almost red hot	Will stand considerable reheating after hardening	Takes a very hard, keen cutting edge: will stand a moderate amount of heating after hardening	Will stand considerable reheating without losing its temper	Will retain its size and shape accurately after hardening and tempering	**See Chart of Plain Carbon Steels**
Uses	Tools for use at high speeds	Tools which are not used under quite as severe conditions as high speed	Hard finishing tools for comparatively fast work	Gripping and heading dies for hot work	Dies, Taps and other tools which must retain their size and shape accurately after hardening and tempering	
Hardening Treatment	Heat to 2300°F. Quench in oil: Draw 1100 Cool in air	Heat to 1800°F. Cool in air: Draw as required	Heat to about 1500°F. Quench in water: Draw as required	Heat to about 1500°F. Quench in water: Draw as required	Heat 1400-1500°F. Quench in oil: Draw as required	

NOTE—The composition of different brands of any of the above classes varies somewhat and consequently the proper heat treatment also varies. For specific instructions consult the manufacturer.

PLAIN CARBON TOOL STEELS

Showing Carbon Content, Temper Numbers, Uses and Temperatures for Forging, Annealing and Hardening

Carbon Content Per Cent	Carbon Content and Temper Number Manufacturer or Dealer* A	B	C	D	E	F	G	H	I	J	K	L	M	Uses	Temperatures Degrees F. for Forging	Annealing and Hardening	Normalizing	Spheroidizing
1.65			A1									7						
1.60			A1		16							7						
1.55			A1		16							7						
1.50			A1		15				1			7		Tools requiring extreme hardness: roll corrugating, chilled roll, turning.		1375 to 1425	1875 to 1925	1275 to 1300
1.45			A2		15				1			7						
1.40	6½	6½	A2		14		14			1	7	7	3X	Roll corrugating, chilled roll turning, graver tools.	1440	1375	1800	1275
1.35	6½	6½	A2		14	6	14	XII		1	6½	7	3X		to 1470	to 1425	to 1850	to 1300
1.30	6	6	C2½	2AA	13		13	XII		1½	6½	6½		Lathe, planer, and slotter tools; brass working tools, drawing dies, razors.	1440 to 1470	1375 to 1425	1725 to 1775	1275 to 1300
1.25	5½	5½	C2½	2AA	13	5½	13	XI	2	1½	6	6½	3					
1.20	5	5	D3H	2½XX	12	5	12	XI	2	2	6	6	3	Small taps; trimming and cutting dies; threading dies; circular cutters; forming and boring tools; twist drills; large lathe, planer and slotter tools; woodworking tools; ball races, peening hammers, granite points; edge tools in general.	1450 to 1500	1375 to 1425	1650 to 1700	1275 to 1300
1.15	5	5	D3H	2½XX	12	5	12	X	3	2	5½	6						
1.10	4½	4½	E3	3A	11		11	X	3	2½	5½	5½	33	Milling cutters; taps; trimming dies; reamers; saw swages; circular cutters; mill picks; woodworking; threading dies; granite tools.	1500 to 1550	1375 to 1425	1575 to 1625	1275 to 1300
1.05	4½	4½	H3½	3A	11	4½	11	IX		2½	5	5½	33					
1.00	4	4	K4H	3½	10	4	10	IX	4	3	5	5	Star	Taps, reamers; mining drills; channeling drills; large milling cutters; punches; axes; cups and cones.	1500 to 1550	1375 to 1425	1500 to 1550	1275 to 1300
.95	3½	3½	L4	4	10	4	10	VIII	4	3	4½	5	Star					
.90	3½	3½	L4	4-5	9	3½	9	VIII		3½	4½	4½	4	Punches; large cutting and trimming dies; drop dies for cold work; mining drills; small shear knives; hand chisels; arbors.	1500 to 1550	1380 to 1440		
.85	3	3	M4H	5	9	3½	9	VII	5	3½	4	4	4					
.80	3	3	M4H		8	3	8	VII	5	4	4	4	44	Large shear knives; punches; chisels; hammers; sledges; cold sets track chisels; forging dies; hammer dies; boiler makers' tools.	1600 to 1650	1400 to 1450		
.75	2½	2½	M4H		8		8	VI		4	3½	3½	44					
.70	2	2	N5	Mild Die and Hammer	7	2½	7	VI		4½	3½	3½		Track-tools; smith shop tools; rivet sets; cupping tools; hot drop forging dies.	1600 to 1700	1425 to 1475		
.65	2	2	N5		7		7	V		4½	3							

Typical Analysis

Carbon.....As stated
Manganese.....15-.30
Sulphur.....Under .03
Phosphorous....Under .03
Silicon.....Under .30

*Letters have been substituted for manufacturer's or dealer's name

original intention to turn out heat treaters, already three of our apprentices, who finished serving their time within the past few months, have left their trades and have gone into the heat treating field. One of them is now in charge of a small hardening room, and we are informed that the other two are slated for foremanships as soon as they have had sufficient practical experience. We do not believe that we have done any harm in weaning them away from their trades as their mechanical training will be of great value to them in the heat treating work.

With this we will rest our case, and leave it to the members of the Society to decide whether our major premise, that the crying need of the heat treating science is a more general education, is correct, and whether our plan of solving the problem seems practicable.

Prof. Goodale (Chairman): These enlightening remarks deal with a field that seems to be a very important one and Mr. Knowlton has given us some excellent ideas on the matter. If there are no comments on their paper we shall proceed to the next paper on our program to be presented by Prof. O. A. Knight of Penn State college.

Professor Knight's Contribution to the Symposium

In the school of mines at the Pennsylvania State college, we gave three curriculi, a curriculum for metallurgists, for mining engineers, and for mining geologists. The first two years is the same for all three curriculi. And we believe that there is an advantage in having the first two years the same, because, first, these years are devoted to such subjects as English, mathematics, physics, chemistry, and such fundamental subjects as are necessary as a foundation for the remaining portion of the curriculum, the last two years. And second, it gives a student a chance to study two years, and then decide what he would like to take up, whether he prefers metallurgy, mining geology, or mining engineering.

I might review briefly the last two years of our courses of metallurgy, mining geology, or the curriculum at the college. The first semester in the junior year there are 2 credits required in physical chemistry, 2 in dynamo machinery, 1 in electrical engineering laboratory; 2 in applied mechanics; 3 in assaying; 5 credits in the principles of metallurgy. These involve laboratory as well as class room recitation; and one hour in coking. The second semester: Metallurgical analysis, 3 credits; power laboratory, one; steam engines and boilers, 2; engineering materials, 2; testing materials, 1; metallurgy of copper, 3; metallurgy of iron and steel, 4; stresses in mine structures,—then there is sort of an option between stresses in mine structures and hydraulics. The senior year is devoted, the first semester to electro-metallurgy, 2 credits; electro-metallurgical laboratory, 3; principle of economics, 3 credits; economic geology, 3 credits; alloys and metallography, 4 credits; ore dressing and coal preparation, 3 credits.

The second semester of the senior year: transportation problems; there is an option here between commerce—15 which is transportation problems, and economics—2, current economic problems—2 or political science—13, political parties—3 credits; engineering law, which embodies engineering contracts, 2 credits; metallurgy—74, advanced metallography, 3 credits; and then we have the metallurgy of gold, silver, lead, zinc and minor metals, 5½

credits; metallurgical thesis, 3 credits; and mining—78, which is the ore dressing laboratory, 1½ credits.

Now, in connection with that, I might say that an analysis of our entire curriculum shows the following results, and this is what I would like very much to have had in the form of a lantern slide for every one to see. As far as a broad general training is concerned, we try to give it. And as Mr. Knowlton was saying, any suggestions or criticisms I can obtain from anybody here, I would certainly be glad to receive. It would be impossible for you to see this on a small scale, but I would be very glad to show it to any one after the meeting. (Indicating course of study in small type). The title of this, in case you should want it is "distribution of subjects in courses in school of mines, 1921-22, Pennsylvania State college." On this side I have the courses for the freshman, sophomore, junior and senior. Here is the semester; and above is the school in which the various subjects are taught. There is the engineering school, liberal arts, mines, natural science. Then here is a column entitled "common" and under that is "hygiene and physiology and military drill." I will summarize briefly what we have here in the metallurgical curriculum. In engineering, we have 20.3 per cent of their credits; in liberal arts, we have 26.68; in the school of mines, 34.32; in natural science, 13.64; in physical education, hygiene and so forth, 5.33; making 100 per cent in all.

One thing I would like to call attention to here, which might seem odd to some of you, there is only 13.64 points required in the natural science school. That is due largely to the fact that at Penn State, geology is taught in the school of mines rather than natural science which is done in a good many institutions. Likewise, mathematics is taught in the liberal arts which gives a rather high percentage, 26.68 for liberal arts, whereas it is very often included in the natural science group.

Now, I have detailed information concerning just what the various courses are during the different periods, that is, for the freshman, sophomore, junior and senior, for the metallurgist, mining geologist and mining engineers, in the whole table as it is worked out.

We believe in, as you will notice, 26.68 points of credit in liberal arts, and the fact I pointed out, there are the English requirements, and the requirements in economics and transportation problems, in giving as broad an education as possible. Now, our present curriculum is the result of a revision that has been made in the last three years. During the last three years we revised our metallurgical curriculum, and we did so by first writing to the alumni of Penn State, back as far as the graduates of 1896. We wrote to such men as Arthur G. McKee, and H. M. Stuart, the superintendent of blast furnaces at Duquesne; and A. M. Neal, superintendent of the Duquesne Iron works, Carnegie Steel company and from then on down the rank, to the 1918 and 1919 graduates; and we asked them to cooperate with us and to write in and tell us what our curriculum lacks, and what it has in it that we can eliminate. By doing that, we have the present curriculum as it is in the catalog.

I would like to call attention to something that perhaps most of you are familiar with, and that is Bulletin No. 150 of the Mining and Metallurgical Society of America; which is entitled "A Report of the Committee on Technical Education." Most of you, as I say, perhaps are familiar with that; it is by A. H. Rogers, chairman; L. C. Gratton, and A. H. Guest. They have there brought out a good many points. They have pointed out

the distribution of time on a percentage basis, devoted to different subjects in the different schools of the country. And I call your attention here again to Penn State, which is very close. At the bottom of this, there is an average given, an average for all schools; and Penn State does not fall far from the average, but understand, I do not mean to imply at all by that that it is at all perfect, because it happens to fall close to the average.

There was one thing that was mentioned in this report of the Mining and Metallurgical society, on page 183. I will just mention a word about it here. I will not take the time to read it, but I will give you the sum and substance of a part of that page. It states that the metallurgical or mining curriculum is outlined by the faculty of the mining school, and many of the subjects are taught in many other schools, liberal arts, engineering and so forth; and as I have pointed out, they are very often taught with the viewpoint of making specialists in English, or specialists in economics and so on, out of the different men, rather than with the viewpoint that they are to become mining and metallurgical engineers.

We try to get around that difficulty by co-operating with the different departments of the college. We have been co-operating particularly with the chemistry department in the last few years, which was not the case several years ago. The way that is handled is that the chemistry department expects us to give a course in metallography for the special benefit of the chemist and we tell them that we will gladly comply with their request and will be glad to give a course in metallography; providing they will specify what they want taught. In the meantime we expect them to return the favor, and reciprocate by giving us courses in chemistry that will be particularly suitable to the metallurgists.

Another thing I would like to mention is that we are strongly in favor of the senior members of the teaching staff, teaching laboratory work. It is quite common in institutions for the heads of departments and men higher up on the staff to do the lecturing and conduct the recitation work, and allow student assistants and men of inferior rank to take care of the laboratory instruction. We believe that the men higher up should give instruction in the laboratory, because they are in a position to inspire the young men and work up the enthusiasm that otherwise would not be obtained. And, in a metallurgical course anyway, we beleve that the real instruction comes in the laboratory, where you are really doing things.

We also believe in a thesis. We believe every student should be required to work out some problem, and submit a satisfactory thesis before graduation. We think this, because it gives the student an opportunity to show his initiative, and to show what he can do in the way of handling problems of his own. And it is a good experience for him to go after some particular problem, the like of which he may run onto, and no doubt will, when he gets out, and he then has some experience in solving it, together with a little help in solving it, if such help is necessary. The second reason we believe that is a good thing is because it gives the instructional staff, the faculty, an opportunity to pick out the students who will likely make good research men. And as we know from the various research meetings and so on which have been held in the last few years, research men are hard to find, or anyway they are scarce.

If there are any questions that any one may have, I will be glad to make an attempt to answer them. And if not, I believe that this about completes my remarks that I have for this afternoon.

I might add. that we have metallurgical inspection trips specified in our curriculum. The second semester of the junior year is given a four hour course in the metallurgy of iron and steel. At the close of the semester, the students are taken on a two weeks iron and steel inspection trip. During this trip all phases of ferrous metallurgy are carefully studied. Each student is required to hand in a complete report of all operations studied.

During the second semester of the senior year, a course in nonferrous metallurgy is given. At the Easter recess period a two weeks nonferrous inspection trip is taken. Both the ferrous and nonferrous trips are planned by an instructor who accompanies the students and is in charge of the work at all times, and explains the operations observed.

The Mining society, which is affiliated with the American Institute of Mining and Metallurgical Engineers is also an important organization at Penn State. The society is composed of the faculty and students of the mining school. Meetings are frequently held at which times prominent mining and metallurgical men are secured as speakers. This brings the student in contact with practical operating men.

If a student wishes to spend five years, he is given an opportunity to study for the degree of Master of Science which may be obtained in one year after the degree of B. S. in metallurgy has been obtained provided the required amount of work is satisfactorily performed.

The degree of Metallurgical Engineer is given to four year graduates of Penn State after they have been in responsible work for at least three years and have submitted a satisfactory thesis.

Discussion of Professor Knight's Contribution

Mr. Thum: I would like to ask what was eliminated from your curriculum as a result of the questionnaire.

Prof. Knight: I am sorry I do not have all of the old catalogs.

Mr. Thum: In general, what did you eliminate as being nonessential and what did your graduates regard as being essential?

Prof. Knight: There was one subject that we did not eliminate although there was considerable debate upon the matter, and that was the course in "stresses in mine structures." Most of the men seemed to be of the opinion that this course should not be eliminated. So that, instead of eliminating the course we made an optional between stresses in mine structures. Hydraulics-1 and laboratory-3. This is one of the things that we made flexible.

Another thing that we eliminated was the course for geologists. They were having a little too much geology, and we thought we could eliminate geology and put in advance metallography. Now, they have eight hours laboratory work in the second semester. If I had an old catalog, I could give you everything and would be glad to; if you should be particularly interested, I could look that up and give you the whole thing in detail. Are there any other questions?

Mr. Thum: May I ask if there was anything added besides an advanced course in metallography, and if the work in economics and such allied subjects were also partly due to this questionnaire?

Prof. Knight: The work in economics I believe has been in the curriculum for a number of years.

Prof. Upthegrove: The credit hours were increased?

Prof. Knight: The credit hours in economics were increased. There were about one and one half hours before, and it was increased to three credit hours now.

Prof. Goodale (Chairman): The next speaker on our program is D. R. Campbell.

Mr. Campbell's Contribution

One of the first problems a metallurgist is confronted with when placed in charge of a heat treating department is to make a study of the equipment in use, in order to determine whether the most efficient furnaces, burners of fuel, pyrometer equipment, quenching tanks and so forth, are in use; in order to attack this problem in the best possible manner, it is necessary to know the principles of furnace construction, of the different type of burners, and methods for determining fuel consumption and so forth.

A university course in heat treating, and room equipment would be of immense practical value to the embryo metallurgist. This course should not only be a lecture course, but should contain laboratory sessions at which the students are allowed to build furnaces, oil, gas and electrically heated and required to determine comparative fuel costs, study various methods of cooling, quenching mediums, and so forth. Such a course should be made compulsory for all students studying chemical and mechanical engineering.

Prof. Goodale (Chairman): Does any one have any remarks to make on this contribution?

Prof. Boylston: Prof. Goodale, I am sure that Case school would be very glad to inaugurate such a course, if the manufacturers would kindly donate the machinery.

Prof. Goodale: If there are no further comments, we shall now call upon Prof. H. M. Boylston of Case School of Applied Science for his paper entitled:

A COURSE IN METALLURGY FOR METALLURGICAL ENGINEERS

By Prof. H. M. Boylston

Steel treaters, manufacturers, employers, chemists, teachers, students, men-at-the-fire, highbrows, theorists, drop forgers, metallurgists, and all others interested in metallurgical education, I bring you greetings from Case School of Applied Science, Cleveland, O., where we train men whom some day you may employ. I am speaking particularly for the department of metallurgical and mining engineering, formerly called the department of mining engineering and will deal only with the course leading to the degree of Bachelor of Science in Metallurgical Engineering.

In my nineteen years of teaching experience I am quite sure that this is the first time I have ever been asked to attend a symposium on metallurgical education. Great credit should be given our American Society for Steel Treating for bringing this symposium about. An exchange of ideas should be encouraged between team captains and coaches, practical men and theorists, employers and teachers as to what

we should teach those men who will some day have to design metallurgical plants, heat treatment departments and laboratories, or manufacture automobiles, airplanes, ordnance equipment, engines, automotive equipment and other high quality steel products without number. I believe you will all agree with me that heat treatment of steel implies quality of product and quality of product requires carefully trained men.

I am going to try to show you in the few minutes which I have at my disposal what we are attempting to do at Case School of Applied Science for those who have selected the profession of metallurgy. A few slides will be shown to illustrate my remarks.

The first slide is a tabular view of the courses prescribed for first year students, and you will note that there are no metallurgical courses listed; in fact the freshman year is the same at Case for all departments.

Course in Metallurgical Engineering
FRESHMAN YEAR

Subjects	Weeks	Hours per week
FIRST TERM		
Trigonometry—Mathematics 2	17	5
French—Modern Languages, 40	17	3
Principles of Exposition—English 31	17	3
General Chemistry—Chemistry, 601	17	3
Chemical Laboratory—Chemistry	17	4
Mechanical Drawing—Drawing, 81	17	10
Descriptive Geometry—Drawing, 82		
Gymnasium	17	2
SECOND TERM		
Analytic Geometry—Mathematics, 3	17	5
French—Modern Languages, 41	17	3
Argumentation and Debating—English, 32	17	3
General Chemistry—Chemistry, 601	17	3
Chemical Laboratory—Chemistry, 602	17	4
History	..	1
Mechanical Drawing—Drawing, 81	17	10
Descriptive Geometry—Drawing, 82		
Surveying—Civil Engineering, 101	17	1
Gymnasium	17	2
PRACTICE TERM		
Topographic Surveying—Civil Engineering, 101, 102	4	44

Figures in bold face type represent laboratory work; others, class room work.

We do, however, give all freshmen a great deal of mathematics including trigonometry in the first semester. Analytical geometry in the second and descriptive geometry and mechanical drawing throughout the year. In the second semester a class room course in the principles of surveying is given. For four weeks during June the whole freshman class takes practical topographic surveying in the field at Camp Case, near Waynesburg, in central Ohio. The camp is situated close to several coal and clay mines. The freshmen also have French and general chemistry during the entire year, with corresponding laboratory work in the latter. Last, but not least, they are given one semester in the principles of exposition and one semester in argumentation and debating. These courses in English are given by a man familiar with the English and public speaking needs of engineers.

In the Sophomore year mathematics is continued with a course in

Course in Metallurgical Engineernig

Subjects	Weeks	Hours per week
SOPHOMORE YEAR		
FIRST TERM		
Calculus—Mathematics, 5	17	5
Spanish—Modern Languages, 50	17	3
Mineralogy—Geology and Mineralogy, 71	17	2
General Physics—Physics, 501	17	5
Mine Surveying—Mining Engineering, 402	17	2
Mine Drawing—Mining Engineering, 401	17	6
Physical Laboratory—Physics, 502	17	6
Mineralogy Laboratory—Geology and Mineralogy, 71	17	3
Gymnasium	17	2
SECOND TERM		
Calculus—Mathematics, 6	17	4
Spanish—Modern Languages, 51	17	3
General Physics—Physics, 501	17	4
Applied Mechanics—Applied Mechanics, 21	17	4
Qualitative Analysis—Chemistry, 605	17	2
Physical Laboratory—Physics, 502	17	6
Qualitative Analysis—Chemistry, 605	17	6
Gymnasium	17	2
PRACTICE TERM		
Mine Surveying—Mining Engineering, 403	4	44

Course in Metallurgical Engineering

Subjects	Weeks	Hours per week
JUNIOR YEAR		
FIRST TERM		
Introductory Metallurgy—Mining Engineering, 407	17	2
Assaying—Mining Engineering, 409	17	1
	17	8
Applied Mechanics—Applied Mechanics, 22	17	4
Quantitative Analysis—Chemistry, 608	17	2
Physical Chemistry—Chemistry, 607	17	2
Elements of Electrical Engineering	17	3
Electrical Engineering, 305	17	3
Quantitative Analysis—Chemistry, 608	17	9
Gymnasium	17	2
SECOND TERM		
Metallurgy—Mining Engineering, 418	17	3
General Geology—Geology and Mineralogy, 72	17	5
Hydraulics—Applied Mechanics, 25	17	3
Technical Exposition—English, 33	17	3
Elements of Electrical Engineer.—Electrical Engineering, 305	17	3
	17	3
Quantitative Analysis—Chemistry, 608	17	1
	17	6
Petrograph—Geology and Mineralogy, 73	17	6
Gymnasium	17	2
PRACTICE TERM		
Mining and Metallurgy—Mining and Engineering, 411,426	4	44

Figures in bold face type represent laboratory work; others, class room work.

calculus, throughout the year. Spanish is also given throughout the year; mineralogy with laboratory work and general physics with physics laboratory are also given throughout the year. A course in

Course in Metallurgical Engineering—Metallurgical Option

SENIOR YEAR

Subjects	Weeks	Hours per week
FIRST TERM		
Business Correspondence—English, 35	17	3
Economics—Miscellaneous, 97	17	2
Determinative Mineralogy—Geology and Mineralogy, 75	17	2
Metallography—Mining Engineering, 420	**17**	**3**
Metallurgical Laboratory	17	**6**
Ore Dressing—Mining Engineering, 405	17	3
Hydraulic and Testing Laborat.—Applied Mechanics 24 and 26	**17**	**3**
Mechanical Engineering of Steel Plants, Mechan. Engineering, 249	17	2
Gymnasium	**17**	**2**
SECOND TERM		
Metallurgy—Mining Engineering, 424	14	3
Physical Metallurgy—Mining Engineering, 427	14	2
Mining—Mining Engineering, 404, 408	14	4
Power Plant Engineering—Mechanical Engineering, 241	14	3
Mine Law, Business and Administration—Mining Engineering, 412. Optional with Geology, 74	14	3
Economic Geology—Geology and Mineralogy, 74	14	3
	14	**3**
Electrometallurgy—Mining Engineering, 425	14	3
Engineering Laboratory—Mechanical Engineering, 247	**8**	**3**
Thesis—Mining Engineering, 431	..	..
Excursions—Mining Engineering, 430	..	**15**

Figures in bold face type represent laboratory work; others, class room work.

the theory of mine surveying is given in the first semester. A course in applied mechanics and one in qualitative analysis with laboratory work, is given in the second semester. In June the combined class of miners and metallurgists take a course in practical mine surveying at Camp Case or elsewhere, performing operations in both surface and underground surveying with the preparation of topographic and mine maps.

In the junior year metallurgical subjects are given for the first time and you will see listed in the first semester, introductory metallurgy which includes pyrometry, calorimetry, typical metallurgical equations and processes, a study of fuels and refractories, physical properties of metals and alloys, etc. Courses in fire-assaying, applied mechanics, quantitative analysis and physical chemistry are also given in the first semester with a course in the elements of electrical engineering lasting throughout the year. In the second semester courses are given in the descriptive metallurgy of iron and steel, general geology, hydraulics, quantitative analysis and petrography, and last but not least a course in technical exposition, (a study of technical writing). In the June practice term, so called, the program is varied; sometimes the metallurgists visit mines with the class in mining and sometimes they visit purely metallurgical works. A year ago last June the class visited iron and copper mines in the Lake Superior region and steel and silver plants in the vicinity of Chicago and Cleveland; while this year, on account of the high cost of traveling, the class visited steel works in Buffalo, Syra-

cuse, Pittsburgh, Woodlawn and Colona, Pa., Youngstown, Canton and Cleveland, O., where some of the members of our society received the class with gratifying courtesies. This trip is an inspection trip and the students do not work at any of the plants, although they are urged to spend their summer vacations in practical engineering work from the time they begin school.

In the senior year, metallurgical students have a course in ore dressing with laboratory work, hydraulic and testing laboratory, mechanical engineering of steel plants, determinative mineralogy, economics, nine hours per week in the metallurgical laboratory where they determine calorific values of fuels, melting points of pure metals and alloys, learning the use of various forms of pyrometers and performing other experiments involving simple heat treatments of steel. This year we are going to include in this course for the first time, certain laboratory experiments carried out at Harvard university for some years and described in a little note book called, Laboratory Experiments in Metallurgy, by Sauveur and Boylston and published originally in 1908. The following experiments are included:

1. Coking and proximate analysis of coal
2. Calorimetry
3. Pyrometry
4. Melting point of tin, lead and zinc
5. Reduction of copper oxide by carbon
6. Reduction of lead oxide by carbon
7. Reduction of copper oxide by copper sulphide
8. Reduction of lead oxide by lead sulphide
9. Determination of thermal critical points of steel
10. Changes in magnetic properties occurring at the thermal critical points
11. Relation between the critical points and the hardening power of steel
12. Hardness produced in high carbon steel by quenching
13. Influence of carbon upon the hardness and hardening power of steel
14. Influence of the nature of the quenching bath upon the hardening of steel
15. Tempering of hardened steel
16. Effect of annealing upon the properties of cold worked steel
17. Modified Metcalf experiment to show the effect of quenching from different temperatures upon the fracture of steel

In this course also, the students prepare for their thesis work which comes in the second semester. In the first semester courses in business correspondence and in the metallography and heat treatment of iron and steel are given. The latter course devotes 3 hours weekly to lectures or quizzes and 6 hours per week to laboratory work, for 16 weeks, and the well known metallographist's bible, written by one of our honorary members, Professor Albert Sauveur, of Harvard university, is used as a text. In the second semester the metallurgists are required to take a course in the descriptive metallurgy of copper, lead, gold and silver, zinc and tin, and a course in electro-metallurgy about half of which is devoted to the electro-metallurgy of iron and steel.

I have inaugurated a new course, known as physical metallurgy,

and am using for a text the second volume of Dr. Hoyt's book entitled, "Metallography; Metals and Common Alloys," so that the students may have some instruction in non-ferrous metallography and the more recent metallographic theories. The seniors also have power plant engineering with laboratory work and a short course in mining. They have the choice too, of a course in mine law or in economic geology. About half the time in the second semester is devoted to a thesis, that is, the working out of some metallurgical problem; this time during my brief residence at Case has in nearly every instance been devoted to the heat treatment or the metallography of iron and steel.

I wish we had a fifth year at Case. The four years work leads to the degree of Bachelor of Science in Metallurgical Engineering but metallurgical engineers should be trained in metallurgical design, should have further experience in heat treatment and the design of heat treatment furnaces, and furthermore should have about one-half year more devoted to research or thesis work.

During such a fifth year, special attention should also be given to the writing of technical papers and reports, for we believe here at Case, that it is impossible to devote too much time to the study of our own language. The engineer is often handicapped by failure to express himself properly and thus is unable to sell his ideas to his employers or to the public. At present the policy of the school is to give a student the degree of Metallurgical Engineer, only when he has received his degree of Bachelor of Science in Metallurgy and has in addition had three years of active metallurgical experience in fairly responsible positions. He must also submit a special thesis on some metallurgical subject. There have been a few cases where men have returned to Case for a fifth year, devoting half of their time to research work and the other half to special courses, but at present the degree offered to these men is the degree of Master of Science in Metallurgical Engineering.

I should like to read an extract from the Case Handbook prepared by C. L. Eddy, professor of railroad engineering, for the Boost Case association. This booklet is handed out to every freshman as he enters college in the fall.

Value of Participation in Student Activities

"While it is recognized that the scheduled work of the curriculum is the important work of the student while in college and that nothing should seriously interfere with that work, still it is believed that there is a value derived from the participation in student activities and that it is well worth the extra effort that it requires.

A man's success in the business world depends upon many things besides the grades he has made while in college. Since we live in a world of other men, in order to make our way, we need, besides a disciplined mind, many other qualities, such as knowledge of men, tact, personality, perseverence, energy, enthusiasm, power to concentrate, ability to work hard and effectively and above all, character.

Emerson has said that a boy goes to college to be taught by his professors, but that it is his classmates who educate him, a statement with some foundation in truth, if by an educated man we mean one who,

besides having a disciplined mind and knowledge, is well developed in those other qualities just mentioned.

It is believed that participation in school activities helps to develop in a man those qualities which are so essential to his success in after life----."

In closing, let me thank you for your attention and let me add that I shall be very glad, indeed, for suggestions either orally or in writing as to how this course may be improved. We realize that we are not turning out metallurgical engineers, but raw material from which the metallurgical plant or its departments can produce the finished product. I think all of you will admit and we do likewise, that raw material is a good name for some technical graduates, but admitting this is half the battle and it then becomes a matter of the degree of rawness. This is the point in which you and we alike are interested, namely, the quality of our graduates and for the improvement of the quality we appeal to you for your co-operation and support.

Prof. Goodale (chairman): That is very good. Each of our speakers have brought out some very excellent ideas of interest and value to all of us. If there is no discussion we will now hear from Col. A. E. White, of the University of Michigan.

Colonel White's Contribution

Prof. Goodale, and gentlemen: I really did not intend to say anything at this meeting, because I think Prof. Upthegrove and Prof. Wood can say something which would add possibly more to this subject than I can. We are of the opinion, however, at the University of Michigan, that we have attempted to give our men, in a four years' course, somewhat too technical a training, and have not given due consideration for the humanities. We realize that in four years' time we cannot turn out an engineer. We wonder if we are treating the boy quite fairly if we give him only engineering, with no background such as would be given to him by history, or such as would come to him by a study of economics and matters of business administration. For that reason, therefore, the work at the University of Michigan in the lines of civil and mechanical and electrical engineering, and metallurgical engineering, bear great points of similarity. We believe that we attempt there just to give a very broad general training in the general field of engineering, with enough of the humanities so that he is a broad gauged man when he leaves school. We are attempting to give him these specialized subjects in his fifth year; and we are making every possible inducement to get the men to remain over for a fifth year.

We are making a special effort to get industrial companies to establish fellowships at the university so that one half of the man's time can be devoted to engineering lines outside of that in which he is specializing, and one-half can be devoted to the technical line in which he is specializing. That is our thought, and that is our purpose. We are trying to do this in such a way as will not wreck the engineering college, because we are not quite convinced that the time is quite here for making the engineering program for our university a five year program. We have seen what has happened in other schools that have attempted to do it, and we know that the attendance has immediately dropped to negligible quantities. Yet, on the other hand, we see the

tendency among the medical schools and dental schools to raise the plane of instruction, which has not been to increase the technical work, but rather to give the man a broader background in the humanities, so that he is a broad-visioned man when he leaves the school. That is the reason we are working on this general program.

I hope all of you can come out to the university. I would be glad to show you what we are trying to do. We are engaged in a great building program. I believe there are something like eight buildings being erected at this moment in Ann Arbor, at a total aggregate cost of something like five millions of dollars. Our president is not at all convinced that our facilities are today adequate. In fact, I know he is going before our legislature, and try to convince them that we need fully five million dollars more for our next two years building program. Of course we realize that we have something that the endowed schools do not have, and the endowed schools have something that we do not have, and that is a difference possibly in the sources of the income. However, I will not go into those subjects right now. They are totally divorced from the subject at hand. I will just try to give you gentlemen an idea of the purpose with which our instruction is carried out. Prof. Upthegrove can give you the different details.

Today one of the speakers has spoken of a proper course and curriculum. I wonder if you will agree that we are right in trying to broaden the course, and introduce more of the humanities, or should we narrow it and turn out a man highly specialized but without the viewpoint of life that he would have if he had the humanities, if we try to put these things into four years. That is just the thought, men, that I have today.

Prof. Goodale (Chairman): We will now hear from Prof. D. J. Demorest of Ohio State university.

Professor Demorest's Contribution

Mr. Chairman, I think the most effective thing that we can do for bettering our work, in whatever line it may be, is by meeting together and talking, and listening to each other's talk and personal discussions.

I come from Ohio State university, the department of metallurgy, and I would like to add this one little point to the discussion. We have a four years' course in metallurgy, with the degree of Master of Metallurgical Engineering as most courses do. We have a curriculum committee which met on an average of once a week for about two hours for about two years. The purpose of that curriculum committee was to discover everything that we might do in order to better our curriculum in the college of engineering, in the university, and to bring us in every way abreast of the times.

Of course, as to this five year course, the five year curriculum idea was under very complete discussion. We finally decided to go on with the four year basis, having changed the college from the semester plan into the four quarter plan. It runs now four quarters, the year around, offering students twice a year every course in the freshman and sophomore year, so that the man who gets out of step can get back into step and not lose time. We open up in our junior and senior years, some courses; in the senior year we have one elective course, so that the students who need special training along the lines of economics,

business administration, factory management and so forth, can get those courses in the senior year, and in the junior year they can get some courses by advising with their teacher. A student cannot elect a course without permission from the head of the department under whom he takes the most of his work. Any student who is deficient in his English, of course, is required to elect English—if that can be called an election.

Now, as to this fifth year, it has bothered us a great deal as to what to do about it. We believe, and I think it is true that if the teachers, the faculty members who teach civil engineering courses, always have as a background of their teaching and always have as the underlying purpose of their teaching the training not merely of engineers, but the making of citizens; and all of their teaching is colored by the spirit that an engineer, in the course of his four years, gets a very thorough training in the humanities, and it makes for good citizenship, after all perhaps even better than if you took a regular classical standard set of courses in history and economics, much as those things are desirable. Now, that gets right down, of course, to the responsibility of the president of colleges, and deans of institutions, the deans of colleges in their selections of faculty members. A faculty member should not be selected merely because he is a keen technologist, but because he is known to have the real spirit of education in him. And I think that if that sort of thing is carried out carefully, and without deviating from that basis of selection of teachers, that an engineer in his four year course is going to be just as well trained in the broad and proper outlook of the citizen as if he had taken a number of formal courses in the arts college. I think the five year course would be better, if the cost were not too great to the students so that it would not eliminate a good many fellows who should get a degree in engineering, who are worthy of it, and all of that sort of thing. I believe that the real training in manhood and citizenship as well as technical keenness and research ability, can be done in four years, if we apply ourselves to it, keeping always as our background that we are not merely turning out an able chap, but a real chap, a real man.

Prof. Goodale (Chairman): If there is no discussion we shall now call upon J. M. Watson of the Hupp Motor Car corporation for his paper, entitled:

PRACTICAL ASPECTS OF METALLURGICAL WORK

In a manufacturing concern such as a truck factory, washing machine plant, passenger car factory, etc., the metallurgist is looked upon as the watch dog of quality, and he is regarded as the logical man, not only to keep the quality of the product at its highest peak, but also to impress upon the other departments this idea of quality and see that these other departments pass this thought along to the doing the actual work and the outside concerns with which they come in contact.

The work of the metallurgist comes in direct relation with the following departments: engineering, purchasing, manufacturing, sales and service. The men in these departments are not educated nor trained along metallurgical lines and it is necessary to deal with them along practical lines, and talk in non-technical language. Hyper eutectoid,

spheroidized, recalescence, etc., sound nice, but don't mean anything to them.

In order to point out more clearly what is meant, each of the departments mentioned will be taken individually and the connection between it and the metallurgist briefly shown.

Engineering Department

In addition to his usual engineering duties, the metallurgist should be in a position to criticize the design of the component parts of the final product, that is, he should be able to point out the weak points in a forging, where cold shots are liable to occur, difficulties that may be encountered in heat treating, due to sharp corners, unequal distribution of metal, insufficient metal around stud holes, etc. In castings, to pick out places where there is danger of shrinkage cracks; difficulty in pouring, or poor arrangement of cores. In stampings, he should pick out difficulties in sinking dies, show where stampings will crack in the die, and point out difficulties in machining. In case of machinery or motor driven vehicles a study of the various types of oil and lubricants is essential. The metallurgist should be in a position to not only make the ordinary routine oil and grease analyses, but should have a general knowledge of their lubricating properties when put in actual use.

To sum up, he should be able to give the designing engineer not only complete data concerning steels or other metals to be used, but should give also information regarding the economical manufacture of the part and difficulties which are liable to be encountered in the fabrication of the piece.

Purchasing Department

When the purchasing department is contemplating placing an order with a concern for forgings, screw machine parts, stampings, etc., the metallurgist is the logical man to be sent to investigate the plant. First he is primarily interested in the steel and its heat treating, but when making his report he should also take into consideration the fire risk in the buildings, the condition of the machinery and its arrangement; the type of work done, the methods of inspection, and the shipping facilities.

To fit the metallurgist to do this, it is suggested that when university classes are taken on tours of inspection, that the student be instructed to observe non-metallurgical points as well as those directly concerned with his studies. An excellent heat treating plant, and a first class steel stock mean nothing if the buildings are fire traps, or the work is not properly inspected when completed.

He should also follow the trend of raw material prices closely and give advice as to the best time for buying.

Manufacturing Department

Coming in contact with the manufacturing department the metallurgist must be in a position to give advice not only concerning the heat treatment of tool steels, but also the shape of the tool, the cutting speed, the most suitable lubricant to use, and various things of this nature. To fit him for this, more time should be devoted to practical work in machine shop practice.

Usually the head of the machine shop will know most of these

things from long experience, but many times in case of trouble the metallurgist is called in consultation and he should be in a position to give advice.

Sales Department

Having assisted the engineering department in designing the part according to good metallurgical practice, helped the purchasing department to pick satisfactory sources of supply, and aided the manufacturing department in the fabrication of the machine, it is up to the metallurgist to sell the sales department from a quality standpoint. In order to do this the metallurgist should have a good foundation in English and have been instructed how to express himself clearly and understandingly without the use of technical terms that mean nothing to his hearers.

Recently a professor from the University of Michigan said that he thought the reason the engineer did not take his proper place among the professions in public opinion was the fact that he is content to do things in a quiet way without the public realizing that he has really accomplished a wonderful feat. In other words the engineer devotes so much time to strictly technical work that he neglects the public side of his profession.

Instructing the sales force to point out the value of the product from a quality standpoint, giving details which can be passed on to the ultimate consumer is an asset that makes the metallurgist invaluable to his concern.

There is one thing that I would like to add here. In a law school, you walk in and you see pictures of all the judges of the supreme court, and the governors, and pictures of men in public life. You can see the same thing in a medical school. But you go into the average engineering school, and you will see pictures of machine plants, drop forge plants and things of that sort. Also in the law schools, the student has the idea that he is not going to be satisfied with anything less than a United States senatorship, or something of that sort. Your engineer has nothing like that held in front of him, and he is perfectly satisfied to go out and take the first job that he can get hold of.

Service Department

When parts are returned to the factory for credit, the metallurgist should examine them carefully to ascertain whether the material is up to the specifications, both as regards material and treatment. The part should also be examined from a mechanical standpoint to see if it has been in proper adjustment or has been subjected to unwarranted abuse and careless handling.

To accomplish all of the above, the writer realizes that perhaps time will have to be taken that is being used at the present time for purely technical instruction and this brings up the final point.

As the average entrance age is 17 or 18 years, the writer believes that this should be done in engineering schools and the courses expanded to include the following:

Factory organization.
Business Administration.
Engineering Contracts and Law.
More English including a short course in public speaking.

Prof. Goodale (chairman): Is there any discussion on this paper?

Mr. Thum: Mr. Chairman, I have listened with a great deal of interest to the various addresses this afternoon. It seems to me that the tendency which is underlying modern engineering education is going toward the longer course, four or five years and even six. Personally, I feel that such a step would be a mistake, principally because it would limit the number of students who could partake of the educational advantages of this country. It is hard enough for a great many of our good students to go for four years, but it will be very much harder to go five years, and I think that a six year course is practically out of the question.

Of course all education is good. I believe none of us would deny that a man who is educated in the liberal arts would make a better engineer than a man who merely had a high school education. I am quite sure that he would make a better engineer; in addition to that, he would make a better citizen.

Now, if the engineering schools are to teach engineering, it seems to me well that they would stick to engineering. If a man wants humanities, let him go to a school which teaches humanity. By that, I do not mean of course that absolutely no attention be given to English or public speaking, but I do think that rather than extend the course of the present four years to five or six years, in order to take up humanities, it would be very much better to examine carefully the present curriculum, and see whether some of the things which are given at present could not be well substituted by other courses.

I have traveled around more or less in the last four years, and during that time I had the honor to be a member of the faculty of the University of Cincinnati; and my experience has been that most of the metallurgical courses at present offered in this country are hybrids; they are merely slight adaptations of mining and engineering courses. Of course, there is an historical basis for that.

When I was a boy, heat treatment was practically unknown. Most of the ore smelting was done close by the mine. The modern large smelter and manufacturing plant was unknown. Things have changed in 30 years; and perhaps in 30 more years the universities will come to the conclusion that they had better do something about it. I speak advisedly because, having been a member of a university faculty, and one not so backward at that, I would like to stake the ordinary university against anything in this world when it comes to sheer inertia. They will get around to it after while, but it seems it is a long time coming.

Again reverting to the fact that metallurgical engineering is more or less the same as mining engineering, I would like to ask why the metallurist should be asked to take mining surveying, for instance, or mining engineering. The metallurgist is not particularly interested in the long haul versus the short haul method of coal mining, or the square-setting method they use for setting stakes, or the testing methods used in the iron country and so forth, and yet he in a great many cases has to take that as a prerequisite for his graduation. It merely seems to me that since there is a great demand for the humanities, it would be very well, indeed, to go after some of these so-called metallurgical courses with a sharp broad-axe, and cut out some of these things which they have had for the last few years, and which have not the remotest connection to the technical end of metallurgy as we understand it at the present time.

Of course, in order to revise and re-vamp a course of that kind, you would have to define metallurgy. That would be a difficult thing to do. But, if you agree with me that it involves the preparation of a metal from its ore, and the preparation of chemical alloys from the metals,—from such a definition of that sort, or a more perfect one, it would be comparatively easy to get a curriculum which would refer to that, and would devote the extra time which it has to such things as English, public speaking, history, economics if you will and some of the other things which are supposed to make an engineer a good citizen.

Now, it has been brought out, and I think very well, that the fundamentals should be taught rather than the specialties. No university can turn out a specialist. In the first place, they have not the equipment; they have not the teachers, the best they can do is to ground a man in the fundamentals. And I think that metallurgy should be taught very well from that standpoint. In the preparation of the metal from its ore, you have several fundamental operations, roasting, smelting and refining. The fundamentals of roasting are practically the same whether you are roasting the ore for the production of sulphuric acid as a by-product, or whether you are roasting sulphur from the iron ore, and so on down the line. There is a great deal in common in the burning of bessemer knap, copper knap and pig iron. And so when they get over into the alloys, you have physical chemistry, and physical metallurgy as a fundamental. In that connection a great deal could be done, and as far as I know, absolutely nothing is being done in this country in the teaching of the practical end of alloys, for example, how to make a brass casting that does not look like a sponge.

Then, going on, of course, you have the broad fields of heat treatment, defective coal and carburization and what not, which applies not only to steel, but to a great part of aluminum and copper alloys as well. Given, of course, a modern curriculum which applies to metallurgy, you come right back to the great question which seems to me that it is not how you teach, or why you teach, but it is the teacher himself that counts for the most. I personally am a great believer in the idea that the student gets the most value from his university training from his instructors and from his fellow students. By all odds, that was the greatest thing in my university life; and observations of other chaps since that time has only confirmed that belief. The prime thing about university life to make a good citizen, to make a good engineer, is to give him the right kind of instructors, men he can look up to; and then give him the right kind of associate, the right kind of surroundings.

Now, unfortunately,—I rather venture on this with some temerity, in view of my many good friends in the teaching profession here—unfortunately, we haven't as yet the highest grade of men teaching metallurgy. I feel that we will not get those men until some of the big business men in the steel and the copper industry, and the other metallurgical industries, suddenly realize that in view of the importance of metallurgy, the attention which they are giving to metallurgical engineering is shameful. There is no other word for it. We have tremendous foundations and endowments in medicine and law, and what-not; and yet here is a fundamental industry of our country, which enables to produce more metals and metal products than any other

country in the world, and yet we have no organized effort in the industry for the teaching of the men who are to carry that work forward. Until that time comes, until the university can properly endow the laboratories and properly endow the chairs, so that they can go out into the industry and compete with the industry for the right metallurgists and put them in the right place, I am afraid metallurgical education in this country is going to be backward.

Prof. Boylston: Mr. Chairman, there is one remark I would like to make there. Mr. Thum spoke about the course in mine surveying that we give the metallurgist. He only mentioned that so I think I ought to say something about it. I think that is one of the courses that does more to humanize the student than perhaps any other course in our school. They go down there for about four weeks, after proper class-room instruction, so that they know how to use the instruments, they climb around in the muck and they live out of doors for a month, in association with their companions and with their instructors, and they have a nice rough time of it, and they learn a good deal more than mine surveying as it is mapped out on paper. I think that is a real humanizing course; that it so in our school anyway.

Mr. Thum: There is one thing that I would like to add. One of our number just touched upon the tendency everywhere for engineering schools to require some practical experience from the men before they graduate. In our course in metallurgy, at Ohio State university, a man cannot get his degree until he has had one whole summer, at least, in practical work in this line. Then he has to come back, with a properly certified letter concerning his work from his employer; and the teacher particularly always takes another metrod of checking up on that man. In addition to that, we have inspection trips, as Prof. Boylston's slide shows you. So that there is a good deal of the practical touch in the course,—as much as can be made possible.

Prof. Upthegrove: I do not like to agree with Mr. Thum in so many things, because our work at the University of Michigan is the outgrowth of the mining course. And it is the outgrowth of the mechanical engineering course, but we have one mining engineer that we are exceedingly proud of, and that is Mr. Brush of Cleveland, who was granted the title of mining engineer from the University of Michigan: but our course does not carry many of the subjects to which Mr. Thum refers, but it rather carries a certain fundamental mechanical engineering course. We believe the metallurgists should have a foundation. It probably has not gone as far as in the metallurgical work as we should like to have it. We should like to have it include certain things along the line of which Prof. Boylston spoke. If manufacturers would only provide the necessary equipment, we would be glad to take up the work of research in the various institutions.

Our metallurgical work really starts in on the instructive basis and follows through with a certain amount of work on fabrication; and we are attempting, although not to any great extent, but just starting in along another line that Mr. Thum mentions and that is in the hope to show a man how to do some of this work in producing what you would call a finished casting. That of course is a little in the distance yet. But, that is the line along which we are really working at the University of Michigan. It is probably due to the fact we are not

connected with a mining course, to begin with, but it really is the outgrowth of mechanical engineering.

Prof. Boylston: I would like to add that in Cleveland we teach our boys how to mold and do certain other foundry operations in technical high school. We do not believe that the college grade of school should teach trades or the art of any particular metallurgical process from the point of view of art itself. We are trying to teach fundamentals also. We have not the same idea as some others as to what fundamentals consist of. We are trying to teach fundamentals, not art. That seems to be a necessity. I o not know where you can get that outside of a college course, only in the school of bitter experience. Taken by and large, our courses are planned from the standpoint of principles rather than practice.

Mr. Thum: Just a word more. I would be extremely sorry if any of the remarks I have made were taken in a purely personal way by any of the men here either against them or their institution. I tried to make them general; and the general ideas, which I so very poorly expressed, were that we yet have to approach metallurgical education as a unit itself and not as a hybrid; and second, the metallurgical industry is not supporting metallurgical education as it should.

Prof Knight: There are just a few words I neglected to say awhile ago in my few remarks that I hurriedly compiled, in regard to the work at Penn State, and that the other one is in connection with the practical work there required. We require four weeks of practical work, that is, inspection work of metallurgical plants. The way we have that arranged is, that in the junior year of the second semester, we give a course, a four hour course in the metallurgy of iron and steel. At the conclusion of the semester, we immediately take a two weeks trip, generally into the Pittsburgh district, and spend two weeks inspecting all phases of metallurgy of iron and steel from the ore as it comes to the blast furnace, and into the various finished products. Then in the senior year, in the second semester, if you will note in the catalog, if any one is particularly interested, we give a course in nonferrous inspection, and we take two weeks of nonferrous inspection. Another thing, in the school for mining engineers, we have meetings as a general rule once a month, after which time we aim to get men from the outside, either big men in the teaching profession, or men in the practical world to come in and give addresses, in order to bring the students into close contact with the actual operating of the plant.

As far as the five year course is concerned, we have the four year course given as liberally as we can; and if any one wants to, we have the Master of Science in Metallurgy. I might mention that in the four years we give the degree of Bachelor of Science in Metallurgy. The Master of Science is given at the end of the fifth year, providing they pass all examinations and requirements. The degree of Master of Science in Metallurgical Engineering is given to students who have the Bachelor's degree, and who have completed three years of work outside, and then have submitted an actual thesis showing that they have actually conducted some piece of important work and have had charge of it.

Mr. McKnight: Speaking entirely from my own very brief experience, I would say that the education of the metallurgist could be di-

vided up to include four phases, that of the fundamentals which have been spoken about, breadth, balance and co-ordination.

It is necessary to dwell long on fundamentals. It is almost axiomatic that an engineer cannot go into the higher studies unless he understands elementary chemistry and physics and mathematics.

As far as breadth is concerned, I think that the subject of specialization can be carried too far. If a man could look ahead 50 years and see that all of that time he is going to be engaged in the production of steel by the open-hearth process, eventually arriving at the position of open-hearth superintendent, at which job he would stay, it would be very easy to teach that man how to produce steel by the open-hearth process; and you could then specialize. But, when a man leaves college, he does not know whether he is going to be a heat treater, an open-hearth superintendent, or any other particular kind of work. He may change into five or six different lines of work. Therefore, I think it is very proper that the colleges should keep their course as broad as possible. It should not be carried to the extreme I was thinking of a moment ago where one of the colleges had a man who was pretty good in football, and he flunked the course in ancient history, and the professor tried to coach him through that course, but he seemed to be bent on fouling it, so that finally the professor gave it up in despair. The man had to play the next day, and the professor said "answer one question, and I will let you out." He asked him, "who dragged whom around the wall, how many times, and why?" And he could not answer the question.

The next point is balance. That is best illustrated in my opinion by a brother of mine who had graduated from a well known eastern university, and was going into the steel business; and in his senior year, he studied Italian literature, Spanish history, political economy, accounting, and field artillery. I think that is what you would call a case of very poor balance in a man's education. It seems to me that he had a very poor balance between what has been termed here the humanizing elements of the course, and the more technical elements. There is a dividing line.

The fourth point, that of co-ordination is brought to my mind because I think there are so many students who study metallurgy and get out into the world as metallurgists who have not co-ordinated the facts. As an example of that, I might take the boy who studied metallurgy at one time, one year, and studied mechanics, bricks, and materials another and studied heat treating another time. It seems to me those courses could be co-ordinated so that the man would take some standard brand of steel—not a brand of steel but some standard analysis of steel, and would heat treat that himself; would pull the test piece on the test machine, and see what physical properties were there; and then would take his metallographical sample and examine it under the microscope. In that way I am quite sure it would be more firmly fixed in his mind, and he perhaps would know them; and the properties would be all the more co-related. Instead of that, in a great many of the schools, the courses are so separated that there is no connection between the properties.

Prof. Boylston: Mr. Chairman, may I say that our so-called thesis work is planned with the idea of co-ordinating all of the previous courses.

Of course, we do not have as much time to do it as we would like to, but our men have five afternoons a week, of about three hours each, and as much extra time as they can cram in for half a year with just that purpose in mind.

I would rather they would learn how to do that, rather than get any actual results, that is, results of value for publication, or anything of that sort.

Prof. Demorest: I might add one thing along that line, and I think it is going to be very effective in our course in metallurgy, and that is running throughout the last two quarters of the senior year we have a course called "metallurgical investigations," in which the class is divided up into perhaps three sections and maybe four, depending upon the type of men we have; and each section then takes a subject, and under the direction of the instructor carries out a complete line of investigation. That is entirely different from his thesis which he has to carry on his own accord. Then the other section of the class carries out an investigation under the direct supervision of the instructors. That has been found very valuable and particularly effective in other work, and we have taken it over in metallurgy. It may be useful to others.

Mr. Wood: There is one point that has been brought up here that I want to mention, about the fifth year. It has been said that it would not be possible in many cases to send the boy to school five years, that it is hard enough to send the boy to school four years. Now, actually that does not present so much difficulty, because in a great many cases there are assistant professorships and fellowships open to students, and they make it possible for the students to stay five years, if they desire, right straight through. In a great many cases you will find this happens: That a man has graduated, and he will go out and take a position and sometimes "find himself" and then he will appreciate the fact that a fifth year would have done him a real good; and we find them drifting back, sometimes on their own expense, and sometimes, but very rarely of course, sometimes coming back on half pay from the concern they are working for. So that I think there is really a feeling for the fifth year, and there is a great deal to commend it and that the financial question is not a serious one.

Prof. Boylston: Mr. Chairman, may I say just a word on that? It seems to me it makes a difference in the fifth year whether you are going to prescribe it as a part of the required course, or whether you make the fifth year optional with those who can afford to do it. My choice would be to have an optional fifth year, and lay out an optional course for them, and allow those who have the additional time and means to take it. It is quite a different thing in the way it works out practically. We handle it in the graduate school course. In most places, it is handled through the graduate school.

Prof. Goodale (chairman): I might say, from my own experience, that our curriculum in both the mining and metallurgical engineering course, is under almost constant revision every year—I have sometimes thought too much so,—because we hardly get the curriculum on one basis in working order before we get a suggestion from some source or the other, some practical suggestion, where they think we can make it better. In that way we attempt to make the curriculum as effective

as we can, so that the men we turn out will make good in the industry. I think perhaps we are working under one condition where we feel competition that some others do not. Of course, we have two schools in Pittsburgh, the Carnegie Institute of Technology, and the University of Pittsburgh,—both schools offering courses in mining and both offering courses in metallurgy. Both schools naturally have a very keen desire along the lines of their students making records. We are very much on our toes towards that end. Every other school is probably just as much so, only they are not so closely in contact with competition as we are in Pittsburgh.

I am sure that we can go on almost indefinitely and have others outline their experiences and their ideas. I feel that I owe an apology to the speakers who have favored us so far. Most chairmen of meetings will say more in words of appreciation of the speakers than I have; but I have not done so merely to save time on the program. It seems to me that each man has brought up a great deal that is well worthy of the attention of us all.

We have a short written contribution from Hugh P. Tiemann of the Carnegie Steel company and another one from D. H. H. DeLong, of the Carpenter Steel Co.

Mr. Tiemann's Contribution to Symposium on Metallurgical Education

While the present discussion is supposed to relate to what is needed for a course in metallurgy a few remarks may be permitted calling attention to certain points essential to any kind of education. These are:

Clear thinking
Clear seeing
Clear writing
Clear speaking

The man who has not been taught to think and to see (both mentally and visually) can never get very far. A knowledge of the principles of logic is necessary in order that he may distinguish between truths and fallacies and between real facts and mere opinions or guesses. Moreover, the trained mind takes nothing for granted, but subjects any data or information to tests sufficiently rigorous to determine their reliability.

Such training will teach a man how to study. Many students are overwhelmed with the mass of facts to be assimilated. By proper methods he will learn by heart the fundamental principles around which the details will naturally and easily fall into place. It is much better to know where to find the details than to attempt to remember them all as this usually leads to endless confusion.

Clear writing and speaking enable a man to convey his thoughts to others so they can be readily grasped and without the obscurity and ambiguity that are so frequently present. A command of language is a tremendous asset not only in carrying out any personal work but also in directing the work of others and in commanding their attention and respect.

I should therefore, recommend the inclusion of ample courses in logic, observation, rhetoric, and elocution.

Coming now to what is essential in the teaching of metallurgy itself this will depend to a certain extent on what application is to be made of it. If pure metallurgy is to be followed consisting of smelting the ore, and refining, working and treating the metal, chemsitry must be the basis, since metallurgy is only one branch of applied chemistry.

Chemistry courses should cover general inorganic, analytical, applied and physical. General metallurgy including a study of heat, fuels and refractories, applied metallurgy and metallography and mechanical testing are obvious.

Courses should also be given in mathematics, including algebra (at least through quadratic equations), trigonometry, geometry and analytical geometry; mineralogy and crystallography, and mechanical drawing. A knowledge of French and German is helpful but not strictly necessary.

Sufficient laboratory work should be given to illustrate the various principles and to familiarize the student with chemical phenomena and methods of analyisis, mechanical testing, the use of the microscope, preparation of specimens, pyrometry, etc. Occasional visits should be made to modern plants manufacturing, working and treating the metal, in order to better understand what is being studied.

In my judgment the greatest stress should be laid on the underlying principles without any special effort to teach the practical details except in the case of work regularly done in a laboratory such as chemical analysis, mechanical testing and metallographic examination. The school is the place to learn theory, and the plant, after leaving the school, the place for practice.

If metallurgical engineering is in question additional subjects are necessary such as mechanical engineering, higher mathematics, through mechanics and thermo dynamics, electrical engineering, and business management. In this case the ability to design, erect and direct are needful.

Contribution By Mr. DeLong entitled:

METALLURGICAL EDUCATION

In outlining a university course which is to prepare students for a metallurgical career in industrial work it appears to the writer that two fundamental lines of training should be considered.

First—The student should be so fully equipped with the fundamentals of science, languages, mathematics and engineering that he may have readily available or can very easily secure the full benefit of past progress and experience in any branch of the metallurgical art.

Second—The student should be given such general training that he will be enabled to make the fullest use of the opportunities which may be presented to him.

The present collegiate training does well with the first of these two divisions, and there is little criticism to be offered in respect to the basic information given, with the possible exception that it is not always thoroughly absorbed by the student, and for this reason it might be well to so arrange the course that more time is spent upon the fundamental theories and principles involved and less time upon the details of specific processes involving their use. Inasmuch as the student has rarely made a decision as to the particular branch of metallurgy in which he will eventually specialize, little is gained by giving courses in specific processes during the collegiate term. This work can, however, be very profitably undertaken by employment in industrial plants during the vacation periods or by limited post graduate work in the university.

There does, however, appear in many cases to be a lack of proper training in the second of the above two divisions, namely, the ability to make fullest use of the opportunities presented.

To improve this condition, there are two particular lines of training which the writer would suggest be given greater attention during the collegiate term than is at present the case. These are as follows:

1. ECONOMICS—A question continually asked the metallurgist and which is vital to his success in commercial work is, "Can your process be operated to show a financial profit"; or "Can a process now in operation be so improved as to cut down the cost of manufacture, or to produce an articles commanding a higher sales value?" In order to properly answer this query it is necessary for the metallurgist to be informed in reference to cost accounting systems; and, further than this, he should be able to sense keenly the financial value of his work. Training in cost accounting, purchasing and selling systems and similar branches of applied economics could readily be incorporated into a metallurgical course in college and would prove invaluable to the graduate in the development of his work.

2. THE ART OF EXPRESSION—Many a valuable suggestion coming from the research department of an industrial plant has failed of adoption with subsequent loss to both the originator and to his employers because of the inability of the metallurgist to present scientific data in clear and simple terms which will appeal to the non-technical mind. While it is understood that the writing of theses is an established part of the metallurgical curriculum, it should be borne in mind that these articles are written for presentation to a superior who has an even more thorough knowledge of the subject than the investigator himself, and criticism of a thesis is often based more upon the accuracy of the data presented than upon the form or clarity of its presentation. In industrial work, on the other hand, the results of research work must frequently be presented to superiors skilled in other than the scientific details of the business involved, and it is essential for this reason that such reports be couched in terms which are readily understood by the lay mind, and that the facts be presented in a logical and convincing manner. The writer would, therefore, suggest the incorporation in the metallurgical course of a thorough training in the higher branches of English and applied methods of expression. While it is agreed that colleges at present maintain a very high standard in their entrance requirements regarding knowledge of the English language, it is believed that the study of its use in connection with scientific terms is not advanced to the proper degree during the college course itself. It is also well to make sure that the graduate is thoroughly familiar with the presentation of facts and data by approved graphic methods, that is, by the use of charts, diagrams, blueprints, etc., as these are of great aid in presenting details of intricate mathematical calculations.

The above embodies two suggestions which have occurred to the writer as a result of his contact with recent college graduates, and he trusts will prove of interest to those having charge of the outlining of collegiate courses leading to degrees in metallurgy.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

NEW QUESTIONS

QUESTION NO. 66. What method and procedure is used in brazing Stellite to carbon steel?

QUESTION NO. 67. What is the reason for the fact that a piece of steel quenched in brine will be harder than the same piece of steel would be if quenched in water, providing that the quenching temperatures and quenching medium temperatures are the same in each case?

QUESTION NO. 68. What is the correct temperature of heating for forging, a .40-.50 per cent carbon steel into automobile crankshafts?

QUESTION NO. 69. Is sulphur up to .10 per cent detrimental to the quality and physical properties of an automotive steel?

QUESTION NO. 70. Is it possible to have a specimen of steel in such a condition that it will show in any one field observed under a microscope at 100 diameters magnification, ferrite, pearlite, sorbite, troostite and cementite?

ANSWERS TO OLD QUESTIONS

QUESTION NO. 27. What is the function of the high phosphorus and the high sulphur content in the so-called automatic screw stock steel?

QUESTION 53. What is the composition of the so-called semisteel?

ANSWER. By Francis B. Foley, Bureau of Mines, Rolla, Missouri.

According to Frank E. Hall in paper presented to the spring meeting of the American Institute of Mechanical engineers semisteel was introduced to supply the need of a metal stronger than ordinary cast iron to supplement the supply of steel for war purposes. Because of its greater degree of fragmentation it was found more useful for certain types of shells. It is not steel but cast iron made in a cupola by a mixture of approximately 40 per cent of pig iron, 25 per cent steel and 35 per cent remelt scrap. In melting, limestone is used for slag making in short heats and in long heats some fluorspar is used in place of some of the limestone. Typical composition runs

graphitic carbon 2.40 per cent, combined carbon 0.60 per cent, silicon 1.25 per cent, manganese. 70 per cent, phosphorus 0.10 per cent, sulphur 0.11 per cent. Hall recommends that the silicon plus total carbon be not less than 4 per cent and that the best results seem to lie between 4 and 4.40 per cent for the total of these two elements. The French specifications, revised, stipulate a tensile strength of not less than 32,000 pounds per square inch, and a hardness not less than that represented by a 4.6 millimeter impression on a Brinell machine at 3000 kilogram load. Under a test requiring the dropping of a 25-pound weight vertically from a height of 12 inches at the start and then repeating, each time raising the weight ½ inch, the specimen, 1½ inches square by 8 inches long shall not fail under less than an 18-inch fall of the weight.

QUESTION NO. 56. *Which is the best method of producing large forgings, pressing or hammering?*

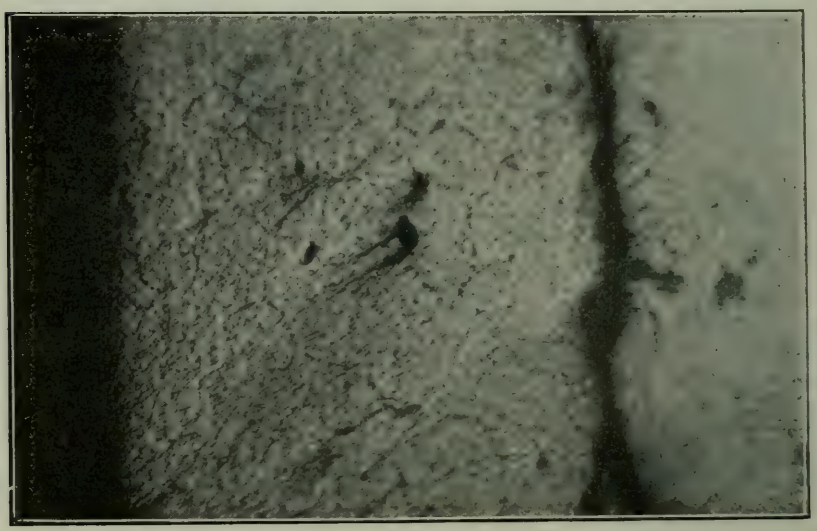
QUESTION NO. 57. *Does repeated heating just above the critical range with subsequent quenching, of a steel specimen injure its physical properties?*

QUESTION NO. 59. *Is a sulphur content of* 0.067 *per cent detrimental to the proper carburizing of a low carbon steel having a low manganese and phosphorus content?*

QUESTION 61. *What are the causes of scaling or spalling of the case of a carburized steel?*

ANSWER. By James Sorenson, metallurgical engineer with the Four Wheel Drive Auto Co., Clintonville, Wis.

Scaling or spalling of a carburized steel is usually caused by the extreme



surface of the case having a considerable amount of free cementite present. The accompanying photomicrograph shows the structure of a carburized bearing race which failed in service. This specimen was etched in sodium picrate which naturally would make the cementite veins appear black. It is clearly seen in this case that the plane of weakness is right next to the hypereutectoid portion of the case, and had this free cementite been eliminated either through suitable heat treatment or preferably prevented in the first place by proper carburization, no doubt, this particular part would have stood up over a much longer period of service. If the carburized case has a carbon content of from .90 to 1.10 per cent, very little trouble will be experienced with scaling or spalling of the case, as free cementite is not very apt to form if the carbon is kept within the above mentioned limits.

It is also very important that the distribution of carbon from the extreme surface of the case to the hypo-eutectoid core should at no place show any indication of a great variation in carbon content, but should rather exhibit a gradual change from the extreme surface of the case to the core. This can be accomplished by using a comparatively slow and uniform carburizing material and at a temperature slightly above the upper AC-3 point of the steel.

QUESTION NO. 62. What is the difference between annealing and normalizing steel?

QUESTION NO. 63. What causes the surface of a carburized steel to become pitted as a result of carburizing?

ANSWER. Pitting of the surface of carburized parts is frequently due to the condition of the steel. Sometimes, where no machining is done on cold-rolled steel, or tubing, the surface shows, after carburizing, a mass of very small pit-marks. These are caused by small particles of scale rolled into the surface which are loosened and drop out when the metal is heated and quenched.

When parts that have been machined show pitted surfaces the fault is probably in the carburizer. Sulphur in the carburizer with a little moisture will produce the condition.

QUESTION NO. 64. To what extent can the deep etching of specimens of steel be applied to routine examination of incoming material?

QUESTION NO. 65. What is the relation between the elastic tensile strength and the elastic compressive strength in ductile steels?

ANSWER. The elastic strength in tension and in compression for ductile steels is usually considered to be the same. This assumption is sufficiently accurate for many purposes. In the problems of combined stress and in built-up compression members, however, it is important to know accurately the relation between the elastic tensile and compressive strengths and particularly to know how the strengths are affected by mechanical treatment of the steel such as the amount of working during the rolling process. Data available

(Continued on Page 588)

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

SERVICE FOR MEMBERS

The Library Bureau of the American Society for Steel Treating is operated to give to the members quickly, reliably and at the minimum expense the following service:

1. A complete copy of the magazine article referred to in any periodical you may be reading.
2. A translation of foreign articles that would help you with your work.
3. A list of references to books and articles on any metallurgical subject.
4. Informing the members of new articles of interest to them as an engineer.

The Library Bureau makes the entire field of literature available to every member, distance is eliminated, for it will copy the desired information and send it to you. It also helps the busy man by supplying information without any expenditure of his time. The charge for this personal work is merely its cost.

The Library Service does not obtain any profit from the work, but does this to make the information contained in the large libraries with which it has connection available to every member. The rates are as follows:

Photo Print Copies of articles, drawings, etc., 25c per 10 x 14-inch sheets.
Searches, abstracts, etc., $2.00 an hour.
Translations, $6.00 per thousand words for French of German; $7.50 and upward for other languages.
Reference card service, giving reference to current magazine articles, $10.00 a year in advance, and 5c for each card mailed.

Members desiring to avail themselves of this service should address Library Bureau, American Society for Steel Treating, 4600 Prospect Ave., Cleveland, Ohio.

SECTIONAL BLANKING AND PIERCING DIES. By Fred R. Daniels in January 1923 *Machinery*.

The above article gives the advantages of sectional dies and the methods used in their construction. It states that sectional dies are used extensively in the production of armature laminations for electric motors and generators, and are also applicable to the manufacture of other classes of stampings containing a large number of perforations. The only essential difference in design between the sectional lamination die and the solid die is that the punch holes in the sectional die are formed by sections arranged radially and accurately fitted and assembled on a plate. These assembled sections form the lower die, as in sub-press construction. The article also describes the methods used in manufacturing sectional blanking and piercing dies.

PRACTICAL NOTES ON THE HEAT TREATMENT OF HIGH SPEED STEEL. By H. K. Ogilvie, in December 1922 *Forging and Heat Treating.*

The above notes were taken from a paper read before the Iron and Steel Institute (British) September, 1922.

The above points out the importance of careful heat treatment of high-speed tools; determination of the quenching and drawing temperatures; mechanical considerations; and the importance of the use of the microscope and pyrometer.

THE DETERMINATION OF SULPHUR BY COMBUSTION IN A STREAM OF OXYGEN. By A. Vita, Chief Chemist in Friendenshutte O. S. In December 1922 *Forging and Heat Treating.*

The above was translated from *Stahl und Eisen,* July 15, 1922. The analytical determination of sulphur in pig iron, steels, ores, slags and fuels by combustion in a stream of oxygen is described in detail in the article. Special cases and limitations are also discussed.

METHODS OF COLD HEADING CAP SCREWS. By John B. Frederick. In December 1922 *Forging and Heat Treating.*

The author presents two methods for cold heading, a correct and an incorrect, and by an analysis shows the truth of the one and the fallacy of the other. The data accompanying this article is original and shows the effort of years of experience in cold heading and wire working, aided by a fundamental knowledge of metallography.

POWER REQUIRED FOR CUTTING METAL. By Fred A. Parsons, Chief Engineer, Kempsmith Milling Machine Co., Milwaukee, Wisconsin. In *Mechanical Engineering,* Vol. 45, No. 1, January, 1923.

This paper gives the results of an investigation extending over a period of more than ten years, the purpose of which has been to determine the fundamental laws governing milling, turning, planing, and drilling operations on the various metals and alloys used in machine construction. A large number of tests have been made on milling machines constructed by the firm with which the author is connected.

The author's results are presented in the shape of formulas and tables by means of which the power required to machine metal in any given case may be calculated, and an example of their use is worked out in detail.

THE SEPARATION AND DETERMINATION OF SODIUM AND LITHIUM BY PRECIPITATION FROM ALCOHOLIC PERCHLORATE SOLUTION. By H. H. Willard and G. Frederick Smith. In *Journal* of the American Chemical Society, Vol. 44, No. 12, December 1922.

The work done in connection with this article was suggested by H. H. Willard and the preliminary work was carried out at the University of Michigan. The final work was done at the University of Illinois.

In this article a method is described for the separation of sodium and lithium based upon the precipitation of sodium chloride from a solution of the perchlorates in anhydrous n-butyl alcohol by the addition of an alcoholic solution of hydrogen chloride. Conditions affecting the accuracy of the process were studied. A table is given showing the density and composition of solutions of hydrogen chloride in butyl alcohol. Test analyses show that one separation gives accurate results even in the presence of large amounts of lithium.

PROMPT AND ACCURATE CARBON DETERMINATIONS. By Thomas Hill, metallurgist, Best Steel Casting Company. In *Western Machinery World*, January, 1923.

In the above article is given a description of the methods and apparatus found satisfactory under difficult steel foundry conditions.

THE PREPARATION AND PROPERTIES OF PURE IRON ALLOYS: II. MAGNETIC PROPERTIES OF IRON-CARBON ALLOYS AS AFFECTED BY HEAT TREATMENT AND CARBN CONTENT. By W. L. Cheney.

The results of the investigations showed that the hardened alloys when drawn back to successively higher temperatures showed certain magnetic transformations; while the annealed alloys showed a decided change in the steepness of the curve and hence a change in the permeability, with a change in the percentage of carbon content.

PREPARATION AND PROPERTIES OF PURE IRON ALLOYS: III. THE EFFECT OF MANGANESE ON THE STRUCTURE OF ALLOYS OF THE IRON-CARBON SYSTEM. By Henry S. Rawdon and Frederick Sillers, Jr. *Scientific Papers* of the Bureau of Standards No. 464.

This article points out that in the manufacture of steel, manganese is one of the most important materials. The effect of manganese upon pearlite is to place upon it a very fine sorbitic structure. The article also states that a decided decrease in grain-size was found in the normalized alloys of high manganese contents.

GASES IN METALS. 1. THE DETERMINATION OF COMBINED NITROGEN IN IRON AND STEEL AND THE CHANGE IN FORM OF NITROGEN BY HEAT TREATMENT. By Louis Jordan and F. E. Swindells. *Scientific Papers* of the Bureau of Standards No. 457.

This article states that it has been found that the only form of nitrogen determined in iron or steel by the acid-solution method is that which is present as combined nitrogen, which probably exists as nitrides of iron or minor parts of manganese or aluminum.

It has also been found that the amount of nitrogen as determined by the acid-solution has been increased by the heat treatment of certain steels.

DIES FOR DIE-CASTINGS. By A. G. Carman, Chief Metallurgist Franklin Die-Casting Corporation, Syracuse, N. Y. In January 1923 *Machinery*.

The above article gives specific examples of the design and construction of dies for making die-castings of the more intricate types.

ELECTRICALLY HEATED INDUSTRIAL FURNACES. By W. Trinks. In December 1922 *Forging and Heat Treating*.

The above article compares the efficiency of electrically-heated and combustion type furnaces. It gives the design of the heating elements and supports as well as the advantages and disadvantages of various types of construction.

Reviews of Recent Patents

1,430,438. Electric Forging and Heat-Treating Furnace. Frederick G. Dawson, Detroit, Mich.

The above invention relates to an electric furnace comprising a heating chamber, a common electrode within said heating chamber, a plurality of other electrodes extending into the chamber and bearing upon a surface of the common electrode, the other electrodes bearing on the common electrode, by reason of their weight, and means for adjusting the pressure between the common electrode and the other electrodes.

1,430,971. Method of and Means for Reducing Ores in Electric Blast Furnaces. Edwin Fornander, Sandviken, Sweden.

A method of reducing ores in an electric blast furnace having a reducing shaft and a laterally enlarged melting room at the lower end of said shaft, which consists in charging ore, limestone and analogous substances at the top of said shaft, which mass will descend through the shaft and collect in the melting room with free surfaces of slope, supplying reducing material directly into said melting room in such a way as to cause said reducing material to form a covering layer on said surfaces of slope while leaving a free space between itself and the lid of the melting room, and removing part of the gases formed in the shaft and returning said part directly to the melting room in such a way as to cause the gas to pass through the layer of reducing material therein.

1,430,987. Electric Furnace. Edward A. Hanff, Pittsburgh, Pa., assignor to Pittsburgh Engineering Works, Pittsburgh, Pa., a corporation of Pennsylvania.

The combination with an electric furnace having a bottom susceptible of conducting electricity and an arcing electrode of a transformer having a secondary winding provided with taps, a connection between one end of said winding and said furnace bottom, a switch for selectively connecting said electrode to any desired one of said taps, and an adjustable reactance in circuit with said electrode.

1,431,621. Method of Manufacturing Steel. Jay C. Beneker, Seattle, Washington, assignor of one-third to Frederick F. McIntosh, Glen Osborne, Pa., and one-third to William B. Skinkle, Coraopolis, Pa.

The method of manufacturing steel containing not more than about .35 per cent carbon and not less than about 1.00 per cent manganese, which consists in blanketing a bath of steel with a slag high in manganese oxides, introducing a silico-manganese alloy in such bath, and eliminating silicon by its reducing action on the manganese oxides of the slag.

1,431,680. Hardening of Thin Steel Sheets. Neil P. Petersen, Montreal, Quebec, Canada, assignor to Gillette Safety Razor Company.

The above relates to an improvement in the method of hardening perforated articles of thin sheet steel by heating and subsequently chilling a stack in which

such articles are interleaved with sheets of high heat conductivity as compared with steel, characterized by the employment of sheets each having an internal opening of such contour as to provide, in connection with the perforations in said articles, an open space within the stack to which the chilling medium has access and in which limited portions of the articles are exposed to direct contact with said medium.

1,433,700. Electric Tool-Tempering Furnace. Ora A. Colby, Irwin, Pa., assignor to Westinghouse Electric Company.

In an electric furnace, the combination with a chamber and a concave roof for said chamber, of a plurality of resistors comprising solid blocks of refractory electrical-conducting material of rectangular cross-section, one of the larger faces of said blocks being so located as to radiate heat against said concave roof, a plurality of hoppers at the rear of said furnace opposite the rear ends of said resistor blocks, a hopper at the front of said furnace opposite the front ends of said resistor blocks, solid terminal electrodes in said hoppers at the rear of said furnace and a mass of electrical-conducting granular material in said rear hoppers interposed between said electrodes and said resistors and adapted to conduct the current there between and to prevent overheating of said electrodes, and a mass of electrical conducting granular material in said front hopper adapted to conduct current between said resistors.

1,434,047. Method of Uniting Hard Steel Alloys to Softer Steel Bars. Jean Hubert Louis De Bats, Zelienople, Pa., assignor, by mesne assignments, to Anatmos Metals and Furnace Corporation, New York City.

The above relates to a method of uniting high-speed steel to a tough steel body, consisting in coating a portion of the surface of the tough steel piece with a suitable brazing metal, placing said piece in a metal mold with a coated surface spaced from the mold wall, and then pouring molten high-speed steel into said space and against the mold, whereby the tough steel body has united thereto a portion of high-speed steel in its cast chilled condition.

1,434,082. Die Shaper. Ernst Bossert. Cincinnati, Ohio.

A die shaper consisting of a frame, a drive shaft journalled in the frame at its top, an intermediate shaft journalled in the frame beneath the drive shaft, a guide plate beneath the drive shaft pivotally mounted at its upper end for forward and backward movement of its lower end, a toggle connected with the plate for effecting swinging movement thereof when the toggle is operated, a tool-carrying side plate reciprocally mounted on the guide plate, an eccentric mounted on the drive shaft, means connecting the eccentric and slide plate for causing reciprocation of the plate when the drive shaft is rotated, and means operatively connected with the intermediate shaft for causing operation of the toggle.

1,443,631. Machine for Cleaning Scale from Annealed Steel. Ralph N. Logan, Philadelphia, Pa.

In a machine of the character stated, the combination of a frame adapted to be reciprocated, supporting means therefor, including a pneumatic counter-balancing means, a source of compressed air for making the pneumatic counter-balancing means effective, and mechanical power devices for reciprocating the frame while pneumatically counterbalanced.

News of the Chapters

SCHEDULED REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Boston—Second Tuesday
Bridgeport—Thursday between 20th and end of month
Chicago—Second Thursday
Cincinnati—Second Thursday
Cleveland—Fourth Friday, Cleveland Engineering Society Rooms, Hotel Winton; meeting at 8:00 p. m.
Detroit—Second and fourth Monday. Detroit Board of Commerce.
Hartford—Friday nearest 10th of month
Indianapolis—Second Monday
Lehigh Valley—No regular night
New Haven—Third Friday
New York—Third Wednesday
Philadelphia—Last Friday
Pittsburgh—First Tuesday
Providence—No regular night. Nov. 10th, Dec. 12th.
Schenectady—Third Tuesday
Springfield—Third Friday
South Bend—Second Wednesday
St. Louis—Third Monday
Syracuse—No regular night
Tri City—Thursday
Washington—Third Friday
Rockford—Second Friday following the second Thursday

MEMBERSHIP AND ATTENDANCE CONTEST

The following arrangement of the chapters shows the percentage of increase of new members based on the number of members each chapter had on September 1st, 1922. While practically all of the chapters have shown an increase in membership over that given in the last monthly letter, those chapters printed in CAPS have passed other chapters.

The percentage of increase in membership is as follows:

	Per Cent		Per Cent		Per Cent
1. Detroit	52.0	10. BUFFALO	20.0	19. Washington	10.0
2. SOUTH BEND	40.0	11. New York	16.7	20. St. Louis	9.6
3. North West	37.0	12. Cleveland	12.8	21. Pittsburgh	9.4
4. BOSTON	30.4	13. HARTFORD	12.2	22. New Haven	9.1
5. Milwaukee	25.4	14. Chicago	11.3	23. Cincinnati	9.0
6. PHILADELPHIA	25.2	15. SYRACUSE	10.9	24. Worcester	7.2
7. L'H'GH VALLEY	25.0	16. INDPLS.	10.7	25. Toronto	3.6
8. Schenectady	23.5	17. Rockford	10.4	26. Providence	0
9. Tri City	20.8	18. SPRINGFIELD	10.3	27. Rochester	0

Attendance at December Meetings

Only 17 chapters have reported the attendance at their December meetings, consequently only that number is listed below.

The reason for the small number of chapters reporting their attendance is probably due to the fact that many regular meeting nights came during the Christmas holidays and consequently the meeting was abandoned or postponed to the early part of January.

In this connection it might be pointed out that the report of attendance for 6 meetings is necessary in order to qualify in the final reckoning of the standings of the chapters in this contest.

Providence had the largest percentage of members present at the December meeting, the percentage of attendance being 62.2 per cent; the second largest percentage of attendance, 54.5 per cent, was shown by South Bend.

The following gives the percentage of attendance for those chapters reporting:

	Per Cent		Per Cent
1. Providence	62.6	10. Cincinnati	29.5
2. South Bend	54.5	11. St. Louis	28.0
3. Syracuse	43.6	12. Detroit	27.3
4. Washington	41.5	13. Chicago	24.7
5. Hartford	36.6	14. Milwaukee	23.0
6. Tri City	34.8	15. Cleveland	22.4
7. North West	32.8	16. New York	16.8
8. Springfield	32.4	17. Pittsburgh	16.3
9. New Haven	31.3		

Standing In The Contest

In order to determine the standing of each chapter in the contest it is necessary to add the percentage of increase in members and the percentage of attendance at the December meeting and divide by 2 inasmuch as each counts as 50 per cent in determining the standings of the chapters.

On this basis we find that the following is the standing of the Chapters on January 1st in the Membership and Attendance Contest:

	Per Cent		Per Cent
1. South Bend	47.8	10. Springfield	21.3
2. Detroit	39.7	11. New Haven	20.2
3. North West	34.9	12. Cincinnati	19.3
4. Providence	31.1	13. St. Louis	18.8
5. Tri City	27.8	14. Chicago	18.0
6. Syracuse	27.2	15. Cleveland	17.1
7. Washington	25.8	16. New York	16.8
8. Hartford	24.4	17. Pittsburgh	12.9
9. Milwaukee	24.0		

Chapters not ranking high at this report should not be discouraged inasmuch as this contest will cover a period up to and including your June meeting and there is much opportunity for chapters not even represented on this list to make very rapid strides in reaching the top.

New Members

There were 86 new members added to the list last month which shows a gain over that for November when 70 new members were added to the Society. It is indeed a very fine showing and judging from the number of applications that are in the office but for which remittance has not yet been

received, the gain for January will probably be larger than for the month of December.

Based on the number of members in each chapter, the following table shows the standing of the 27 chapters of the Society. Detroit is still the largest chapter, keeping a lead of about 50 members over its nearest competitor, Chicago.

Those chapters printed in caps have advanced their position over that occupied in the December report, while those in italics have a lower position. The standing is as follows:

1. Detroit
2. Chicago
3. Pittsburgh
4. Philadelphia
5. Cleveland
6. New York
7. Hartford
8. Milwaukee
9. Boston
10. Lehigh Valley
11. *North West
12. *Syracuse
13. Worcester
14. *Indianapolis
15. *St. Louis
16. Rockford
17. Tri City
18. BUFFALO
19. WASHINGTON
20. **Cincinnati*
21. *Schenectady
22. Springfield
23. Providence
24. SOUTH BEND
25. *New Haven*
26. Toronto
27. Rochester

(*)—Tied

BOSTON CHAPTER

The Boston Chapter of the American Society for Steel Treating held its January meeting on Tuesday evening, the 23rd, at 6:30 p. m., at the Worthington Pump and Machinery Corporation's Blake & Knowles Works, 265 Third St., East Cambridge.

The meeting was preceded by a dinner served in the shop cafeteria of the plant at 6:30 p. m.

The speaker for this meeting was W. J. Kunkel of the forge department of the Blake & Knowles works, who gave a very capable paper, entitled "Forgings." Following Mr. Kunkel's paper, a short talk was given on the Worthington Diesel Engine built at the works of the Worthington Pump and Machinery Corporation and one of these engines was on exhibition and in operation.

Following this program the forge department of the plant was open for inspection. The department was in operation and a demonstration of the manufacture of crankshafts and other engine forgings, as well as ring forgings, forgings of Monel metal and Tobin bronze was witnessed by all. A demonstration showing the advantages of the acetylene cutting torch in forge shop practice was performed for the visiting members.

This meeting was very well attended and proved to be a decided success.

The February meeting is scheduled to be held in the Boston plant of the Edison Electric Illuminating Company. The subject for this meeting will be "Electricity and its Application to Heat Treating Furnaces." Demonstrations are being arranged and a real live meeting is planned.

CHICAGO CHAPTER

On January 12th the Chicago chapter of the Society held its regular monthly meeting at 8 p. m. in the Chicago City Club rooms, corner of Jackson Blvd., and Plymouth Court.

James P. Gill, metallurgist of the Vanadium-Alloys Steel Co. presented his paper entitled "The Tempering of Tool Steels."

The printed circular announcement of this meeting anticipated to some degree the details of Mr. Gill's paper and commented as follows:

"The title sounds very simple. It would seem to indicate that all that is necessary to do to temper a piece of tool steel is to heat it up until it shows a color comparable to that of a bale of rye straw grown on George McNallys' farm, which is located on the N. E. ¼ of the S. W. ½ of Section 23 north range 13, County of Whistleville, North Dakota, and throw it in a tub of brine of a sufficient density to float one Idaho potato before being baked and containing one piece of good grade all wool piano felt so as to prevent tool loosing temper when it strikes bottom of tub.

"Mr. Gill will make the definite statement that 'them days are gone forever.'

"He is going to prove to us that there is no connection between the tempering of a piece of tool steel and a bale of straw or even a flock of pigeons. He will even go so far as to say that a red-headed boy can temper tool steel but that it is not essential that he be red-headed. This must be so because Mr. Gill hasn't a red hair in his head. He also will say that goats have nothing to do wtih the heat treatment of tool steels even though they be fed on green ferns grown on the hillside among the tall and stately cypress trees.

"From the above statements it can be seen that Mr. Gill has some real dope for the members. If your committee ever finds another goat tied up in the corner of a Chicago hardening room, they will know that the members from that plant failed to attend the January meeting."

Although Mr. Gill did not follow the outline as given in the announcement, he did present a very capable, instructive and interesting paper on the subject of hardening and tempering tool steeels. It will undoubtedly be recalled that Mr. Gill presented a very capable paper at the Indianapolis annual convention of the society, which won for him the silver medal of the society. He is a recognized authority on the metallurgy and metallography of tool steel.

The usual get-together dinner was served at 6:30 p. m. in the dining room of the Chicago City Club. A very good turn-out was had at both the dinner and the meeting following.

Announcement has recently been made that Harry Blumberg, former secretary and treasurer of the Chicago chapter of the society has accepted a very responsible position with the A. O. Smith Corp. of Milwaukee, Wis. In making this change, Mr. Blumberg has resigned the office of secretary and treasurer of the Chicago chapter which he has so capably filled for the past three years.

Arthur G. Henry, special representative of the Vanadium-Alloys Steel Co., has been elected to succeed Mr. Blumberg as secretary and treasurer of the chapter.

CINCINNATI CHAPTER

The regular monthly meeting of the Cincinnati chapter was held Thursday evening, January 11th, at 8 p. m., in the Ohio Mechanics Institute rooms, Canal and Walnut Sts. The program for this meeting consisted of a paper by W. R. Klinkicht, assistant engineer of tests of the Pollak Steel Co., entitled the "Forging and Heat Treating of Large Sections," illustrated with lantern slides.

Mr. Klinkicht, who is an authority on the subject of forgings and heat

treating of large sections presented a very interesting and instructive paper, outlining in detail the processes of the manufacture of heavy forgings and their subsequent heat treatment.

Following the presentation of this paper Mr. Klinkicht answered many questions which were put to him by members and guests present.

This meeting was well attended and proved to be exceedingly interesting and instructive to all those who had the good fortune of attending.

Cleveland Chapter

The Cleveland chapter of the American Society for Steel Treating held its regular January monthly meeting on Friday evening, the twenty-sixth in the rooms of the Cleveland Engineering society, Hotel Winton. The program for this meeting was an illustrated paper by H. J. French, physicist of the Bureau of Standards entitled "Some Factors Affecting the Heat Treatment of Steel."

Mr. French presented his paper in a very capable and interesting way and brought out many points of interest and value to heat treaters. Following this paper a rather lengthy and interesting discussion on the practical aspect of the heat treatment of steel was held and many points of interest and value were brought out.

The usual get-together dinner was served at 6:30 p. m. in the English room of the Hotel Winton.

DETROIT CHAPTER

The Detroit chapter of the society held its first January meeting on the fifteenth of the month in the rooms of the Detroit Board of Commerce, at which time R. T. Herdegen of the Dominion Forge company read a very capable paper on "Forging Practice for Automobile Parts."

Mr. Hergegen's paper brought out many points of interest and following his paper a very lively and interesting discussion was held.

The second January meeting of the Detroit chapter was held Monday evening Jan. 22 at 8 p. m. in the rooms of the Detroit Board of Commerce and was preceded by a get-together dinner, served at 6 p. m.

The speaker for this meeting was Karl Herrmann, engineer of the Studebaker corporation, who gave a very capable paper on "Gears and their Relation to the Automotive Industry." This paper was a continuation of Mr. Herrmann's paper which was delivered last fall at the production meeting of the Society of Automotive Engineers and proved to be a very interesting paper, especially to automobile engineers and to heat treaters.

A very lively discussion followed the presentation of Mr. Herrmann's paper and many valuable points pertaining to the heat treatment of gears were brought out in this discussion.

HARTFORD CHAPTER

On Friday evening, January 12th, the Hartford chapter of the American Society for Steel Treating held its regular monthly meeting in the assembly hall of the Hartford Electric Light Co., Pearl St., Hartford, Conn.

The program for this meeting was a paper presented by E. E. Thum, associate editor of *Chemical and Metallurgical Engineering*, entitled "Educating the Metallurgist and the Management."

Mr. Thum being in close touch with the current developments in metallurgy and heat treatment of steel through his connection with the *Chemical and Metallurgical Engineering* publication is particularly fitted to discuss the problem of heat treatment from the viewpoint outlined in the title of his paper.

Mr. Thum's paper proved to be exceedingly interesting and brought out many points, showing some of the fallacies which are prevalent in the handling of metallurgical problems and in the handling of men to carry out the details of these metallurgical problems in the various plants.

Mr. W. H. Eisenman, National Secretary of the Society, was a guest of the Hartford chapter at this meeting and gave a short talk on several matters of interest to both the National Society and the local chapter.

This meeting was well attended and proved to be of considerable interest to all who had the privilege of being there.

INDIANAPOLIS CHAPTER

The regular January meeting of the Indianapolis Chapter was omitted for the month, due to the fact that the class in heat treating was commenced January 8th, and it was felt that the regular January meeting was not needed this year.

The next regular meeting of the Chapter will be held on February 13th at which time the subject of "The Open Hearth Practice of Refining Steel" will be discussed.

A great deal of enthusiasm for the new course in heat treating has been shown by the members of the Indianapolis Chapter, and this feature of the chapter's activities will undoubtedly prove to be a decided success.

LEHIGH VALLEY CHAPTER

The Lehigh Valley Chapter of the American Society for Steel Treating held a joint meeting with the Engineers Club of the Lehigh Valley on Friday evening, January 19th at 8 p. m.

The speaker for this meeting was Dr. Richard Moldenke, consulting metallurgist. The subject of his paper was "Cast Iron from the Standpoint of the Engineer." His paper was a most interesting one, and contained many interesting anecdotes from the wide experiences and travel that Dr. Moldenke has enjoyed. He is one of the authorities on the subject of cast iron as well as malleable iron, having been associated with the Foundrymen's Association as well as an honorary member of numerous other scientific organizations. He is the author of numerous papers and books on special researches on malleable iron and cast iron.

This meeting was very well attended and proved to be interesting and instructive to all.

Prior to the regular meeting the usual get-together dinner was served at 6:30 p. m. in the Hotel Bethlehem.

MILWAUKEE CHAPTER

On Wednesday evening, January 17th, 1923, the Milwaukee Chapter of the American Society for Steel Treating held its regular January meeting in the rooms of the Blatz Hotel.

The usual get-together dinner was served at 6:45 p. m. to a goodly number of members and guests.

The program for this meeting was a paper by James P. Gill, Metallurgist of the Vanadium Alloys Steel Company, entitled "The Tempering of Tool Steels."

Mr. Gill handled his subject in a very capable way, and brought out many points of interest in the hardening and tempering of tools.

The speaker has had wide experience and training in the metallurgy of tool steels, and handled his subject in a most capable manner.

NEW HAVEN CHAPTER

On Friday evening, Jan. 19 the New Haven chapter of the American Society for Steel Treating held its regular monthly meeting in the assembly room of the New Haven Gas Light company, 70 Crown St. New Haven, Conn.

V. E. Hillman, metallurgist of the Crompton and Knowles Loom Works, Worcester, Mass., presented his paper entitled "The Effect of Cold Work on Steel." This paper was illustrated with stereoptican slides and discussed the influence of the heat treatment on cold drawn, cold rolled and cold upset steel.

This paper also discussed the effect of cold working upon the grain size of the steel prior to heat treatment.

Following the paper of the evening an informal smoker was held at which time John Stevenson entertained the assemblage in his usual jovial manner.

NEW YORK CHAPTER

The New York chapter of the American Society for Steel Treating held its January meeting in the assembly room of the Merchants association of New York, ninth floor the Woolworth building, Jan. 17 at 8:15 p. m.

Frank H. Starkey of Hartford, Conn., was the speaker of the evening. His paper was entitled "The Spark Test Method for Testing Steel."

This paper proved to be a very interesting subject and was very capably illustrated both by blackboard sketches and by actual demonstrations on a grinding wheel. The speaker demonstrated the characteristic sparks for many of the different steels and the application of the spark test method for the identification of steels in actual practice.

In accordance with the request in the announcement of this meeting, many members brought specimens of steels for identification by the speaker in using the spark test method of analysis.

The usual get-together dinner was served in the Post Keller restaurant at 6:30 p. m. which is located in the Woolworth building.

NORTH WEST CHAPTER

The North West chapter of the Society held its regular December meeting in the Manufacturers Club Rooms, 200 Builders Exchange, Minneapolis, Minn.

The subject for this meeting was entitled "A Model Heat Treating Plant" and was open to the discussion of all members of the chapter.

The Ideal Manufacturing Co. of Minneapolis, manufacturers of automobiles, having called upon the members of the North West Chapter for their advice in the layout and equipment of its heat treating plant, as well

as the methods and practice to be used in heat treating the various parts of its automobile, have their construction work well under way.

The tentative plans prepared by Hans J. Meyer, the consulting engineer, retained by the Company, provide for a one-story building, 100 x 400 feet, which is estimated to cost, including the equipment, $400,000.

W. E. Johnston has been appointed chairman of the chapter's committee to study these questions and to report its recommendations. The committee presented its preliminary conclusions for discussion at this meeting. The Committee realizing that it needs the advice and counsel of all the members of the Chapter, welcomes any criticisms or suggestions they care to make. This meeting was devoted largely to a discussion of the layout and equipment of the plant.

The North West chapter of the society held its regular monthly meeting Jan. 16 at 7:30 p. m. in the Manufacturers club of Minneapolis. 200 Builders Exchange building.

The program for this meeting was a paper presented by James P. Gill of the Vanadium-Alloys Steel Co., Latrobe, Pa., entitled "The Tempering of Alloy Tool Steels."

Mr. Gill, who is a very capable metallurgist, is an authority upon the subject of tool steel and presented many practical thoughts in outlining his experiences with the problems that men had in the hardening of tools. His paper was well illustrated with lantern slides and proved to be exceedingly interesting to all those who had the privilege of hearing him.

A very interesting and helpful discussion followed Mr. Gill's paper.

PHILADELPHIA CHAPTER

The Philadelphia chapter of the American Society for Steel Treating held its January meeting Friday evening, January 5th, at 8:15 p. m., in the Engineers Club, 1317 Spruce St., Philadelphia.

The usual get-together dinner was served at 6:45 p m. in the club rooms of the Engineers Club.

The program for this meeting consisted of two papers, the first entitled "Case Hardening" by C. B. Callomon, metallurgical engineer with the Driver-Harris Co., Harrison, N. J., who presented a very capable paper on carburizing and carburizing containers. This paper developed considerable discussion on the subject of carburizing and proved to be of extreme interest to the members and guests present.

Following Mr. Callomon's paper E. E. Thum, associate editor of *Chemical and Metallurgical Engineering*, presented his paper entitled "Mutual Education of the Metallurgist and Management."

Mr. Thum developed numerous excellent thoughts pertaining to the mutual education of both the metallurgist and the executive.

The chapter was honored by the presence of the National Secretary, W. H. Eisenman, who gave a brief talk pertaining to matters of interest to the National Society and the local chapter.

The meeting was very well attended, about 45 being present at the dinner, which was served preceding the meeting, and about 200 members and guests were present for the meeting proper.

PITTSBURGH CHAPTER

The regular monthly meeting of the Pittsburgh chapter of the American Society for Steel Treating was held on January 2nd, 1923, in the meeting rooms of the Chatham Hotel, Pittsburgh, Pa.

Professor W. Trinks, head of the Department of Mechanical Engineering, Carnegie Institute of Technology, gave an informal talk on the automatic control of industrial furnaces discussing in detail various systems which have been developed during the past year, particularly during 1922.

Professtor Trinks' discussion covered both gas and oil and electrically-fired furnaces.

This paper proved to be exceedingly interesting and instructive to those who had the privilege of hearing it.

Following this paper Mr. M. Homi, metallurgist for the Tata Iron & Steel Co., Bombay, India, discussed every particular development of that company, and predicted for the steel industry in India a very promising future, particularly as ore, coal and coke and limestone can be secured within a radius of 200 miles and the native labor is very cheap. He stated that a good grade of pig iron is being produced for $5.00 per ton.

This meeting was well attended and proved to be exceedingly instructive and interesting to all.

The usual get-together dinner was served at 6:30 p. m. in the dining room of the Chatham Hotel.

RHODE ISLAND CHAPTER

The January meeting of the Rhode Island chapter was held in the new home of the Providence Engineering society at 44 Washington street, Providence, R. I., Jan. 12, 1923.

Chairman, Franklin opened the meeting by introducing Professor Hall of the engineering department of Brown university. Professor Hall is president of the Providence Engineering society and gave a short address of welcome to the steel treaters and invited them to use the new headquarters of the engineering society, and likewise he explained the benefits of membership in the engineering society.

Mr. Franklin introduced E. C. McCormick, assistant metallurgist of the Crompton Knowles Loom Works, Worcester, Mass., who presented a paper entitled "The Use and Abuse of Pyrometers."

Mr. McCormick first reviewed the history of pyrometers and then went into the details of the instruments, explaining how the metals in the fire end produced the electric current and how this current is transmitted and the strength of it measured by the galvanometer. He explained the manufacture of the parts going to make up a pyrometer and pictured in detail on the blackboard, the inside working mechanism of a millivolt-meter. Mr. McCormick had a pyrometer with him which was used to demonstrate his talk.

Numerous points in reference to the care and proper use of pyrometers were brought out and much good advice was given on what not to do.

Mr. McCormick's talk was very comprehensive and instructive. At the close of his talk he answered many questions and cleared up many of the misapprehensions of those present.

SOUTH BEND CHAPTER

The January meeting of the South Bend chapter was held on Jan. 10 at the Studebaker corporation plant No. 2. About 40 members and guests were present.

R. E. Lewton, chairman of the research committee the South Bend chapter, delivered a very capable and interesting talk entitled "Some Fatigue Properties of Spring Steel." This talk was illustrated by slides and microphotographs.

Discussion on Mr. Lewton's paper will be held at the February meeting.

The main feature of the evening was Professor E. G. Mahin, Professor of Analytical Chemistry at Purdue university. His subject was "Nonmetallic Inclusions in Steel." This lecture was also illustrated by slides which showed graphically conditions of nonmetallic inclusions. An interesting discussion followed Professor Mahin's lecture.

The South Bend chapter is planning for a large meeting in February. Mr. Thum, associate editor of *Chemical and Metallurgical Engineering* will address the chapter on the subject "Relation of the Metallurgist to the Management."

ST. LOUIS CHAPTER

The regular monthly meeting of the St. Louis Chapter of the American Society for Steel Treating was held Monday evening, January 16th, in the American Annex Hotel. A get-together dinner was served at 7 p. m. to a rather large turn-out of members and guests.

The program for this meeting consisted of a paper by J. E. Burns, metallurgist of Indianapolis, Indiana, who presented a very capable paper entitled "Carburizing Methods and Uses."

Mr. Burns is an authority on the subject of carburizing, having had years of practical shop experience in charge of metallurgical work in automotive plants, combined with field experience which has carried him into hundreds of shops, so that he was able to give the members some of the most up-to-date information on the subjects of carburizing and case hardening.

Mr. Burns' paper proved very instructive and interesting to all those members and guests who had the privilege of hearing him. Following the paper an interesting and lively discussion was held.

SYRACUSE CHAPTER

On Friday evening, January 5th, the Syracuse chapter of the American Society for Steel Treating had the honor of listening to Enrique Touceda, consulting engineer for the American Malleable Castings Association, who presented a very capable paper on malleable iron.

Enrique Touceda is a recognized authority on the subject of malleable iron and presented some very interesting facts upon this subject, pointing out its valuable use in the industries as well as the manner in which it is controlled throughout the manufacturing and producing industries.

Through the efforts of the Malleable Association the quality of malleable cast iron has been constantly increased and controlled until at this time it holds a very enviable position in the automobile and allied indus-

tries, being a very favorable competitor to cast steel, as well as structural and forged steel.

Prior to the regular meeting hour the usual get-together dinner was served at the University Club at 6:30 p. m. An unusually large attendance was had at both the dinner and the meeting following.

TRI CITY CHAPTER

The Tri City chapter of the American Society for Steel Treating held its monthly meeting in the Davenport Chamber of Commerce rooms on Thursday evening, Jan. 18. The meeting was called to order at 8 p. m. by the chairman. The chairman gave the results of the membership and attendance contest as of Jan. 1, 1923 and stated that the Tri City chapter was in fifth place. Increased membership and regular attendance at meetings was urged. A. H. Putman was appointed chairman of the membership committee.

The speaker of the evening was James P. Gill, metallurgist of the Vanadium-Alloys Steel company, Latrobe, Pennsylvania who spoke on "The Tempering of Tool Steels." His talk was illustrated by lantern slides. Mr. Gill first showed the ordinary table of tempering colors and temperatures. He then showed that the tempering color was a function of time as well as temperature. In other words, with the same temperature, the entire range of tempering colors may be secured by varying the time element. Mr. Gill showed characteristic curves, plotting tempering temperature against Brinell hardness. These curves were given for alloy steels as well as for carbon steels. Mr. Gill brought up the question as to whether these steels should be slowly or rapidly cooled after tempering. He quoted from several authorities showing that there is a great deal of conflict on this question. Results of test on nickel steels were stated giving the Izod values for the steels corresponding to the various methods used in cooling from the tempering temperature. There was considerable discussion of the paper.

The meeting was then turned over to Robert B. Kerr, who started a round table discussion on the subject of "Molten Baths for the Heat Treatment of Steel." The advantage and disadvantages of lead and various salts were stated and discussed by various members.

It was announced that the next meeting would be held on Thursday, Feb. 22 at the Davenport Chamber of Commerce. The speaker will be Paul D. Merica who will talk on "Nickel and Nickel Steel." Upon a motion of Mr. Kerr, seconded by Mr. Drew, the meetings for the remainder of the year will be held at the Davenport Chamber of Commerce.

The meeting adjourned at 10:20 p.m.

WASHINGTON CHAPTER

The January meeting of the Washington Chapter was held Friday evening, January 26th, 1923, in the Auditorium of the New Interior Department Building, corner of 18th and F. Sts., N.W.

B. H. DeLong, metallurgist of the Carpenter Steel Company, Reading, Pa., was the speaker for this evening.

He presented a very capable paper entitled "The Manufacture of Alloy Steels." Mr. DeLong described in detail the methods and practices used

by the Carpenter Steel Company in the manufacture of alloy steels by the crucible, electric and open-hearth processes.

Due to the fact that Mr. DeLong has had long experience in the production of all types of alloy steels, including high-speed steels and his intimacy with their application in the industry particularly fitted him to present this paper in a most interesting and capable way.

A most profitable discussion followed Mr. DeLong's paper, and many points of interest and value were brought out.

WORCESTER CHAPTER

The January meeting of the Worcester chapter was held at the plant of Walden Worcester company, 475 Shresbury St., Worcester, Mass. The feature of this meeting was a paper and demonstration by Charles Karl of the Vanadium-Alloys Steel Co., showing the hardening of high-speed tools.

In addition, F. J. Evans of the Surface Combustion company gave an illustrated talk on surface combustion as applied to heat treating furnaces.

This meeting was very well attended and proved to be a very instructive and profitable one to all the members and guests who had the privilege of attending.

Question Box

(Continued from Page 571)

indicates that the elastic compressive strength of ductile steel is somewhat greater than the elastic tensile strength except in the case of soft steel. The amount of working or rolling has a marked effect upon the elastic tensile and compressive strengths of steel. Steel which has been rolled into comparatively thin plates or small shapes has an elastic compressive strength approximately 5 per cent greater than the elastic tensile strength whether the elastic strength is judged from the proportional limit, useful limit point, or yield point. In the case of soft steel having relatively little working in the rolling process, the compressive proportional limit is much greater than the tensile proportional limit, while the yield point in compression is somewhat less than the yield point in tension. It appears, therefore, that the criterion of elastic strength may be of much importance, that the tension test so generally used to judge of the elastic properties of steel is not wholly reliable, and that it may be necessary to resort to auxiliary compression tests for material to be used under certain conditions of combined stress and for critical compression members, at least, until test results and the treatment received by the material can be correlated through more extensive experimental investigations. To what extent the increased compressive strength due to rolling may be attributed to compacting, causing a denser material or attributed to the arrangement of the crystals of the constituent elements in steel or to other factors is not definitely known. The problem offers opportunity for fruitful experimental work.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A repesents Associate Member; S represents Sustaining Member; J represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

NEW MEMBERS

ARTZ, R. R., (A-11), Vanadium Alloys Steel Co., Latrobe, Pa.
ATHY, L. C., (Jr-12), 139 West 11th Avenue, Columbus, Ohio.
BAKER, R. E., (M-1), Rock Island Arsenal, Rock Island, Ill.
BEDWORTH, R. E., (M-1), Westinghouse Research Laboratory, E. Pittsburgh, Pa.
BLAKE, L., (M-1), Standard Motor Parts Company, Lebanon, Ind.
BOND MANUFACTURING CORP., (S-12), Wilmington, Del.
BOYLE, C. L., (A-10), 1298 Baniteau Avenue, Detroit, Michigan.
BROOKFIELD, W. B. Jr., (M-1), 868 Ostrom Avenue, Syracuse, N. Y.
BROWN, H. E., (M-1), 3615 Superior Avenue, Cleveland, Ohio.
BRUCE, Y. J., (Jr.-12), 34 Chittenden Avenue, Columbus, Ohio.
COLKET, T. C., (M-12), 2008 DeLancey Street, Philadelphia, Pa.
COOPER, CLARK, Jr., (M-1), Box 414, Millersburg, Pa.
CUSAC, W. R., (M-9), 1669 Hazelwood Avenue, Detroit, Mich.
DICKMAN, O. D., (M-1), 1085 Cortland Street, St. Paul, Minn.
EVERETT, A. M., (M-12), 29 Warren Avenue, Somerville, Mass.
GALBRAITH, NELSON, (M-1), 717 Rush Street, South Bend, Ind.
GELDER, R. H., (Jr.-12), 176-15th Avenue, Columbus, Ohio.
GRIFFITHS, Wm. E., (Jr.-1), 59-16th Avenue, Columbus, Ohio.
HAMILTON, S. R., (M-1), 2334 E. Grand Blvd., Detroit, Mich.
HAWKINS, R. D., (Jr.-12), 2190 Indianola Avenue, Columbus, Ohio.
HENRY, C. J. W., (M-1), 116 Sanders Avenue, Scotia, N. Y.
KELLY AXE MFG. CO., (Sb-12), Charleston, W. Va.
KELLY, W. C., (S-1), Kelly Axe Mfg. Co., Charleston, W. Va.
KINSEY, C. R., (M-1), 15216 Loomis Ave., Harvey, Ill.
LEETE, A. C., (A-10), Box 38, Hamburg, N. Y.
LENNOX, G. A., (A-10), Driver-Harris Co., Harrison, N. J.
MAHLIE, C. C., (Jr.-12), 1027 Waldeck Street, Columbus, Ohio.
MALIN, J. A., (Jr.-11), 70 E. Clopin Street, Germantown, Pa.
McOMBER, M. F., (M-12), 6340 Douglas Ave., E. Pittsburgh, Pa.
MENGEL, A. C., (M-1), Ballston Lake, N. Y.
OWEN, R., (M-1), 6932 Keystone Street, Philadelphia, Pa.
PERRY, A. S., (M-1), 226 McClellan Street, Schenectady, N. Y.
PETERSON, G., (A-1), 1420 Pennsylvania Blvd., Philadelphia, Pa.
RENIKOFF, L., (M-12), 613 14th Ave. S., Minneapolis, Minn.
SCHAFER, H. W., (M-12), 1005 S. Lafayette St., South Bend, Ind.
SCHNELL, WM., (M-12), 584 Marsten Ave., Detroit, Mich.
SCHUVER, N. L., (A-12), 26 N. Munroe Terrace, Dorchester, Mass.
SOLDERITCH, L. J., (M-10), 2240 Erskine Street, Detroit, Mich.
SYKES, G., (M-10), Gray Tractor Co., Minneapolis, Minn.
TOWNSEND, J. H., (S-12), 1330 Buttonwood Street, Philadelphia, Pa.
VOGEL, H., (M-1), Union Electric Steel Co., Carnegie, Pa.
WENTWORTH, R. W., (A-12), 514 Merchants Bank Bldg., St. Paul, Minn.
WRIGHT, C. R., (Jr.-11), 320 John St., Rockford, Ill.
WRIGHT, E. C., (M-10), University, Alabama.

CHANGES OF ADDRESS

BARKER, T. E., from Denver, Colorado, to 210 Larch Ave., Elmhurst, Ill.
BELKNAP, R. E., from Bethlehem Steel Co., Chicago, to Bethlehem Steel Co., Boston, Mass.
BRILL, M., from Cleveland, Ohio, to 552 N. 2nd St., Philadelphia, Pa.
FLOYD, P. E., from Indianapolis, Ind., to 1238 Washington Blvd., Chicago, Ill.
GERMAN, J. P., from Waterbury, Conn., to Bennett Metal Treating, Elmwood, Conn.
GRAHAM, E. H., from Heppenstall Forge & Knife Co., to 618 Book Bldg., Detroit.
GRAHAM, W. F., from Hartford, Conn., to Curtis Bay Copper & Iron Wks., Baltimore, Md.
HOFFSTETTER, F. B., from R. K. LeBlond Machine Tool Co., to Seiffert & Woodruff Co., Cincinnati, Ohio.
HORNER, W. C., from Montcalm St., to Box 1005, Indianapolis, Ind.
HUGHES, A. F., from E. 62nd St., to 8127 Blackstone Ave., Chicago, Ill.
JAYME, W. A., from Canton, Ohio, to 19 Pomander Walk, New York City.
JOHNSON, F. E., from Lexington Ave., to 132 155th St., Harvey, Ill.
KINGSBURY, J. A., from 503 W. Third St., Mishawaka, Ind., to 314 Angela St., South Bend, Ind.
KOPENHOEFER, C., from Summit Ave., to 820 Mt. Hope, Cincinnati, O.
LOEFFLER, G. O., from Carbon Steel Co., to Bellefield Dwellings, Pittsburgh, Pa.
McFARLAND, J. L., from Box 954 to 11 Columbia St., Schenectady, N. Y.
NEIL, E. B., from Harrold Motor Car Co., to Fisk Bldg., New York City.
NETHAWAY, F. R., from Concord, Detroit, to 607 W. Barnes St., Lansing, Mich.
RIMBACH, R., from W. North St., to 327 McKee Place, Butler, Pa.
SCHAGRIN, H., from Tulsa, Okla., to 1008 E. 42nd Place, Chicago, Ill.
SMITH, E. C., from Book Bldg., Detroit, to Central Steel Co., Massillon, Ohio
SWANDER, C. B., from Wagner Elec. Co., to 5621 Maple Ave., St. Louis, Mo
WALKER, E. C., from N. Blvd., to 175 N. Humphrey Ave., Oak Park, Ill.
WARD, W. J., from Corry, Pa., to Union City, Pa.

TRANSACTIONS

of the

American Society for Steel Treating

Vol. III Cleveland, March, 1923 No. 6

THE BUSINESS OUTLOOK

THE business depression which has been so persistently with us for the past two years has been improving very decidely within the last few months. In industry and commerce the prevailing sentiment of cautious hopefulness is rapidly changing to one of full-hearted optimism which is the fore-runner of prosperity.

This attitude is being clearly reflected in the advancing prices on the stock markets and the very marked increase in the volume of business which is being transacted throughout the country. As evidenced by the current trade reports, there are long lists of industries which report increased prices on their goods and predict still futher increases.

The business cycle through which we are passing will have its reward for those who display enterprise and practice caution. It is, however, appropriate for those engaged in manufacturing or commercial enterprises, that they keep in mind the lessons which were learned back in the days of 1919 and 1920 and profit thereby.

Numerous phases of industry are showing very marked improvement, among which the agricultural industry, the building construction industry, the railroad equipment industry, the oil and petroleum industry, and the iron and steel industry are rapidly approaching a point where it is necessary for them to revise their production schedules in order to supply the demand for their products. This increasing demand likewise brings about increased prices and this is exactly the condition today, prices have been increased and predictions are that there will be further advances.

The iron and steel industry has a greater demand upon its present output than can be supplied by this output. The industry as a whole is working at about 90 per cent of its capacity, and a further increase in production may be difficult due to labor shortage.

Automotive manufacturers are increasing their production schedules, the agricultural implements industry are experiencing rapidly advancing sales and the building construction industry program, including heavy construction work on large structures, is far greater than it was last year, which in turn makes a greater demand upon the steel industry's output.

The pig iron production of the country is rapidly increasing and showed a production for the month of February of better than 90 per cent of the peak output during the World War.

The business outlook for the coming years is particularly bright and the all-important feature of this new prosperity is that quality and service must be paramount.

WINTER SECTIONAL MEETING WELL ATTENDED

THE winter sectional meeting of the society held in Chicago on February 8 and 9 proved to be a decided success as evidenced by the number of members in attendance and the quality of the papers presented.

The meetings were held in the City club. Registration began at 10 a. m. Thursday morning and continued until luncheon was served at noon. The first technical meeting was opened at 2:30 p. m. by Harold F. Wood, metallurgist, with the Wyman-Gordon Co., Ingalls Shepard division, Harvey, Ill. After expressing words of welcome on the behalf of the Chicago chapter of the society to the visiting members, who came from all parts of the country, he turned the meeting over to J. Fletcher Harper, metallurgist with the Allis-Chalmers Co., who presided during the technical paper session. During this afternoon session three papers were read. The first one, "Characteristics of Air Cooling Curves" was presented by E. J. Janitzky. metallurgist with the Illinois Steel Co. Mr. Janitzky's paper was published in the December, 1922, issue of TRANSACTIONS, and as a result a valuable discussion followed the reading of this paper.

The second paper was presented by Robert G. Guthrie, metallurgist with the Peoples Gas Light & Coke Co. of Chicago, dealing with the subject of light. This paper specifically discussed incident, monochromatic and polarized light as used in making microscopic examinations and photomicrographs of metals. The author illustrated his paper with stereopticon slides which brought out the salient points of the paper. One photomicrograph which was exhibited was taken at 11,000 diameters magnification and enlargement.

The third and last paper of the afternoon session was presented by E. E. Thum, associate editor of *Chemical and Metallurgical Engineering,* New York, entitled "Educating the Metallurgist and the Management." This paper was a very capable presentation which developed the author's ideas on the necessity of metallurgists in general to show their respective managements that their departments are not items of over-head and a liability but instead that they are an asset and an earning department. Suggestions as to how this proof could be successfully established were developed in this paper.

At 6:30 p. m. a dinner was served to over 250 members and guests. Following the dinner the toastmaster, H. F. Wood, called upon a number of the directors of the society for their remarks.

Only one technical paper was scheduled for the evening meeting and this was presented by Howard Scott, associate physicist of the Bureau of Standards, Washington, entitled "The Effect of High Temperature Quenching on the Microstructure of High-Carbon Steels." This paper was well illustrated with stereopticon slides showing photomicrographs of typical structures obtained in this investigation. Mr. Scott's paper appears in this issue of TRANSACTIONS.

On Friday, Feb. 9 the board of directors of the society held a meeting at which time a general business session was carried through.

Three plant inspection trips were scheduled for the day. Members assembled at the City club at 10:00 a. m. and were divided into parties, one party going to the Ingalls-Shepard division of the Wyman-Gordon Co., Harvey, Illinois, the second to the Interstate Iron & Steel Co., and the third to the Illinois Steel Co. Approximately one hundred members took advantage of these inspection trips.

THE EFFECT OF HIGH-TEMPERATURE QUENCHING ON THE MICROSTRUCTURE OF HIGH-CARBON STEELS

By Howard Scott

Abstract

The first sections of this paper deal with the conditions necessary to produce austenite at ordinary temperatures in a plain high-carbon steel and some metallographic properties of this constituent. In contradiction to current views, it is shown that austenite can be obtained with a very slow rate of cooling compared with that necessary to produce martensite in lower carbon steels provided that something over 1.5 *per cent carbon is dissolved. This was accomplished by heating a* 1.78 *per cent carbon steel to nearly* 1100 *degrees Cent. The transformations in cooling steel are next considered with particular attention directed to the effect of the rate of cooling and thermal stress on the distribution of martensite and troostite. It is shown that the periphery of cylinders during quenching is under tensional stress and this condition is favorable to the precipitation of troostite. Finally several significant aspects of the transformation of austenite to martensite are discussed.*

Introduction

IT IS often possible by means of the examination of extreme cases to secure enlightenment on complex phenomena whose crucial features are vague or weakly defined under normal conditions. Such a possibility is presented in the hardening of high-carbon steels. The structure of these steels when quenched in the approved manner reveals little of significance, but when quenched from very high temperatures it is coarser and shows striking characteristics. Furthermore, if the steel contains sufficient carbon, the resulting product may be austenite and the problem is thereby simplified by the elimination of a complicating change, martensite formation, which may be caused to occur subsequently. In view of these possibilities a study was made of the structural changes accompanying the high-temperature hardening and subsequent treatments of three plain high-carbon steels.

This field of investigation is not new, but is only partially developed. Osmond's book, first published in 1904 and translated by Stead (1)*, gives photographs of austenitic carbon steel and of the surface change produced by immersion in liquid air. Hanemann (2) has conducted the most complete microscopic investigation of this type of steel. He notes certain effects of tempering and describes the cementite needles found in an austenitic matrix, which he confuses with other acicular structures. Benedicks (3) and Maurer (4) have also contributed some information on this subject, the work of the latter author being particularly valuable as it is the only source of data on the physical properties of austenitic carbon steel. Scott and Movius (5) have noted significant facts revealed by heating curves of such steel. However, none of these authors appear to have recognized the considerable

*The figures appearing in parentheses following the names of authors, refer to bibliography appended to this paper.

A paper presented before the Chicago sectional meeting of the society, February 8, 1923. The author, Howard Scott, is associate physicist of the Bureau of Standards, Washington, D. C.

difference existing between the structure near the surface and that of the interior.

The work originally planned involved only a study of the effect of several variables on the microstructure of a carbon steel of 1.78 per cent carbon content, but the novelty of the results in this line suggested the desirability of similar experiments on lower carbon steels. These later experiments were concerned primarily with the distribution of martensite and troostite under various hardening conditions, an important, but almost totally neglected, field for investigation.

Experimental Procedure

The compositions of the steels investigated are given in Table I. The A steel was in the form of ⅝-inch hexagonal bar, the B and C steels ½-inch round bars and the D steel 1 x ¾-inch cast bar. The A steel was annealed in the laboratory to facilitate cutting. All specimens were ½ inch in diameter and 1 inch long unless otherwise noted. Heat treatments at temperatures above 300 degrees Cent. were conducted in an electric muffle furnace, no precautions being taken to avoid oxidation. The specimens heated for quenching were held 10 minutes after they came to a color matching the

Table I

Chemical Composition of Steels Investigated

Mark	C per cent	Mn per cent	Si per cent	Sul per cent	Phos per cent	Condition
A*	1.78	0.20	0.09	——	——	As forged and annealed
B	1.16	0.21	0.17	0.010	0.013	Mill annealed
C	1.04	0.25	0.38	0.013	0.018	Hot rolled
D	1.15	12.0	0.55	0.015	0.062	As cast

*The author is indebted to R. P. DeVries, metallurgist of the Ludlum Steel Company for this steel and its analysis.

pyrometer tube. Quenching consisted of dipping the specimen well below the surface of the quenching medium, holding it still until black, and then stirring until cold, the object being to compensate for the slower cooling as the specimen approached the bath temperature. For tempering, the specimen was maintained at the temperature selected, plus or minus 10 degrees Cent., for ½ hour and cooled in air. When the temperature required was under 300 degrees Cent. an oil bath was used. After treatment the specimens were cut in half transversely with a wet flexible cutting disc and one of the new surfaces used for examination. They were etched in 10 per cent picric acid in methanol, unless stated otherwise. The micrographs were taken at a magnification of 500 diameters and the macrographs at 4 diameters with vertical illumination. A slight reduction has been made in reproducing the photographs. The exact magnification is given in each caption.

Constitution of the Austenitic Carbon Steel

The steels investigated may be broadly classified as austenitic and martensitic according to whether they are susceptible of being maintained completely austenitic to ordinary temperatures or not. The former steels are the 1.78 per cent carbon steel A and the Hadfield manganese steel D while the latter are the 1.16 and 1.04 per cent carbon steels B and C. The justification for this classification will appear in the experimental data.

Microstructure

In considering the austenitic carbon steel the first variable to study is

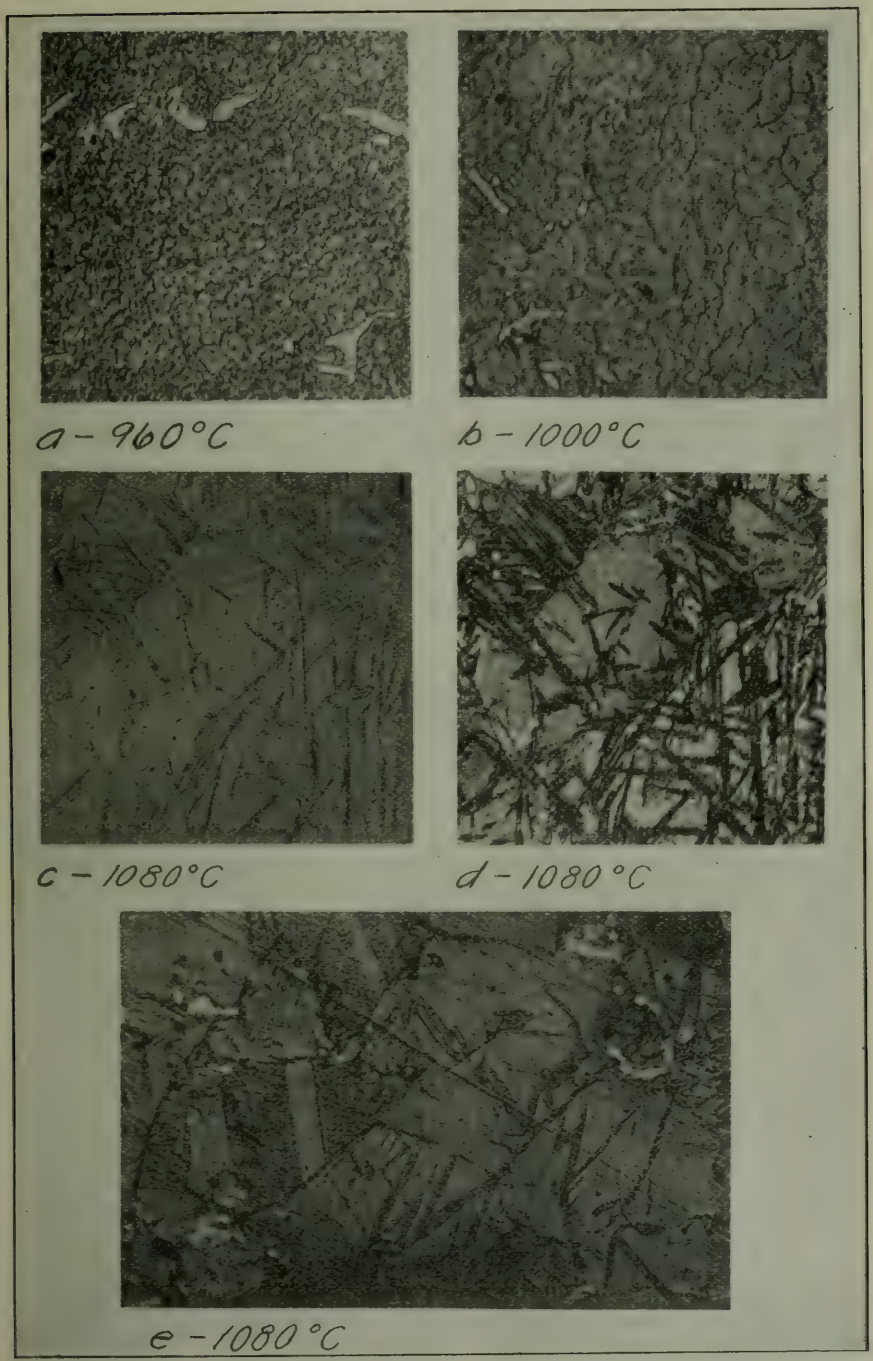


Fig. 1.—Steel A quenched in water from the temperatures indicated. (a), (b) and (c), characteristic structures of the interior; (d) same area as (c) etched longer; (e) area near edge. X 450.

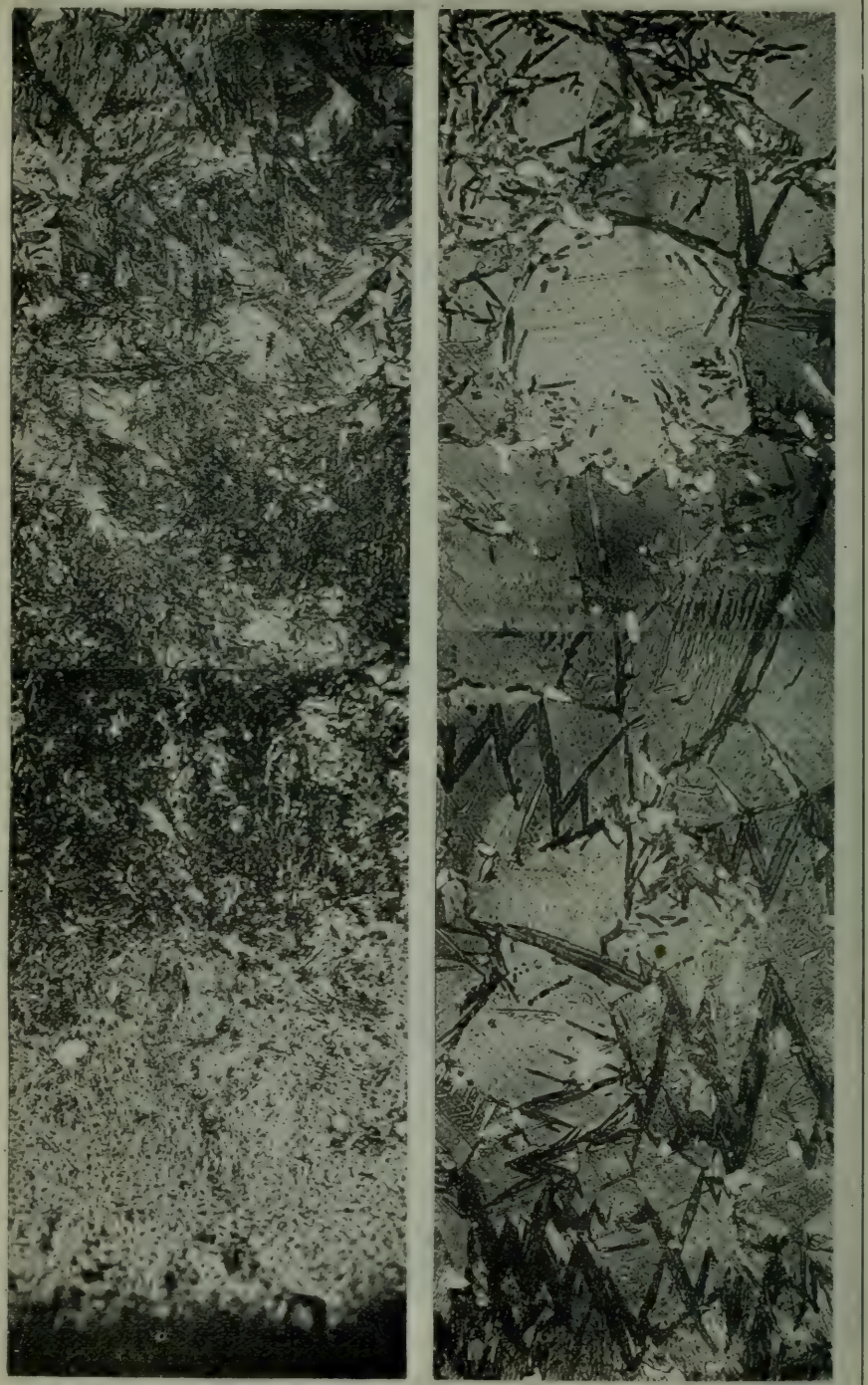


Fig. 2—Structure near the surface of steel A after quenching in water from 1080 degrees Cent.; upper left edge of micrograph shows the surface of metal while upper right and lower left edges are coincident, the photograph being continuous

obviously the quenching temperature. In this steel the cementite is not completely dissolved below the eutectic temperature, that is, the amount of dissolved carbon varies continuously with the temperature from 730 degrees Cent. to something over 1100 degrees Cent. The effect of this variable is shown in Fig. 1. With the lower quenching temperatures, (a) and (b), the structure is characteristic of the normal hardening of high-carbon steels, but an increase in quenching temperature to 1080 degrees Cent., hereafter called the high-temperature, produces a distinctive modification. In the interior of the specimen (c) a structureless matrix is found broken up by grain envelopes and long feathery needles. Deeper etching, (d), darkened certain areas, but this appearance could not be consistently produced. Near the surface, (e), the needles are absent, but numerous twinned crystals and broad angular markings, hereafter called zig-zags, are found in the polyhedral matrix.

The change in structure from the surface inward is shown in Fig. 2. The structure of the left hand third is martensitic and contains no free cementite, grain envelopes, needles or zig-zags. That next toward the center contains free cementite, twins and angular markings, but no well-developed needles and is the structure referred to as that of the edge. The normal structure of the interior just begins on the extreme right. This condition is typical of all specimens quenched from the high temperature.

A smaller specimen, ¼-inch in diameter, had a structure characteristic of the edge throughout, Fig. 3 (a) and (b). In this case a white zig-zag suggestive of lightning was found near the center (a) and was not removed by deep polishing (c). Twins and slip-bands were produced in this specimen by squeezing in a vice, (d) and (e).

To investigate the possibility of a relation between the acicular structure and the shape of the specimen other forms were used, namely, a sphere and a cylinder with a ratio of length to diameter of 4 to 1, Fig. 4. For comparison the structure of a standard shape is given as etched in picric acid, (e), and in sodium picrate, (f). The differences, however, do not appear to be significant.

A comparison of Fig. 4 (e), oil quenching, and Fig. 1 (c), water quenching, shows no appreciable structural difference for these extremes of quenching rate. Further experiments in decreasing the cooling rate were undertaken with the object of producing the next lower order constituent, Fig. 5. Quenching a larger specimen in oil, (a), did not accomplish this. As specimens of still larger diameter were not available it was necessary to resort to air-cooling. A ¼-inch diameter specimen cooled before a drying fan produced the desired result, (c) and (d). The black constituent is evidently troostite equivalent to that formed in martensitic steels on quenching. It is uniformly distributed over the whole section except at the extreme edge and is surrounded by a matrix identical to that produced by faster cooling. Cooling at a still slower rate produced only troostite, (b).

Having determined the conditions necessary to produce austenite in this steel, the effect of tempering on its structure was examined. Fig. 5 (e) shows the structure of the interior as quenched in water and (f) as tempered at 200 degrees Cent. In Figs. 6 and 7 the results of higher tempering temperatures are shown for the interior of the specimen on the left and for the edge on the right. Tempered at 200 degrees Cent., a new brown lens-shaped constituent has appeared and at 250 degrees Cent. has extended over the greater portion of the section. However, there is no definite indi-

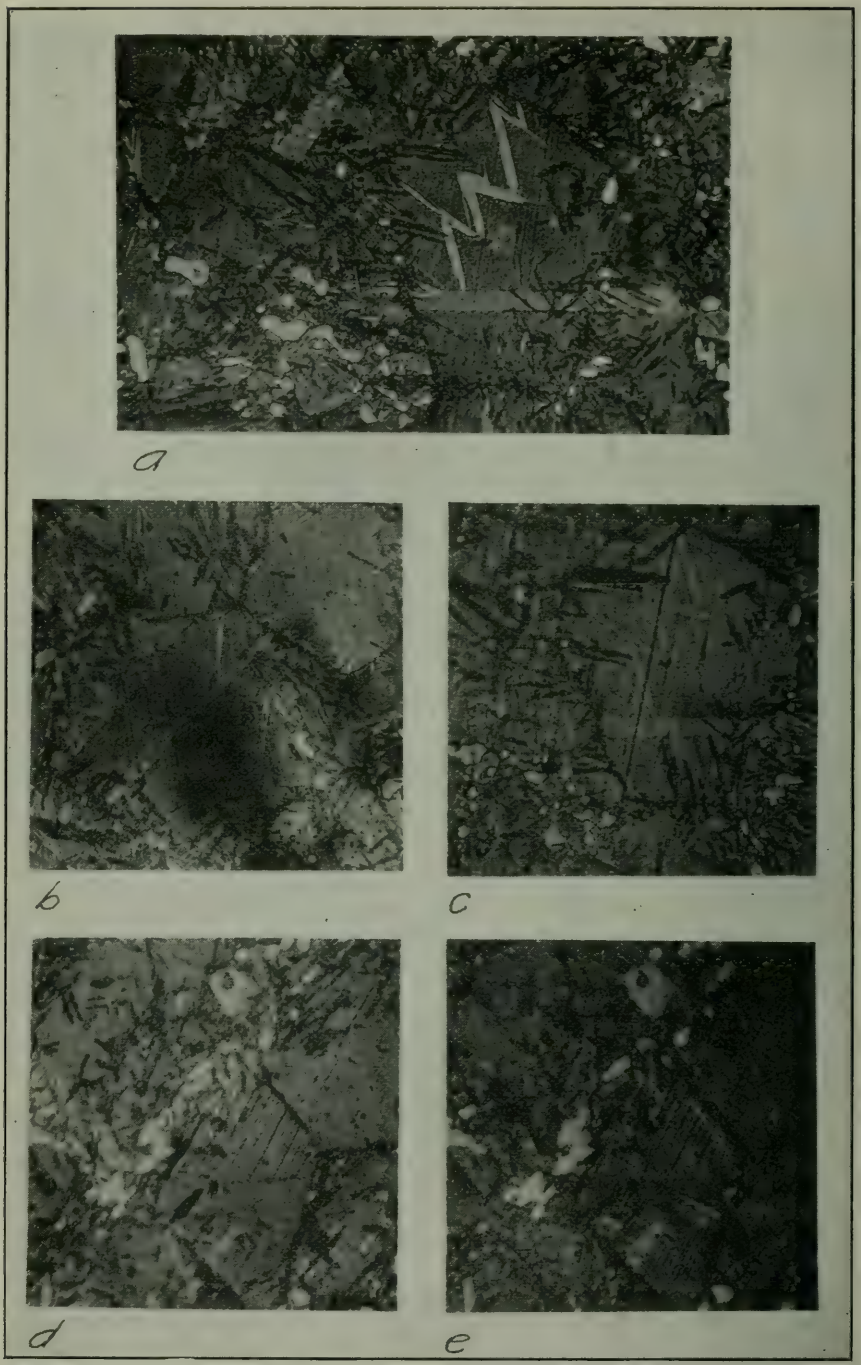


Fig. 3.—Specimen of steel A ¼-inch diameter quenched in water from 1080 degrees Cent. (a), twin and zig-zag in a large grain near the center; (c), the same after deep polishing; (b), twins near the edge; (d) and (e), twin and slip-bands produced by strain. X 450.

cation of tempering near the edge. After tempering at 300 degrees Cent., the original white matrix has completely disappeared in the interior, though a few splotches are left in the edge area. Tempered at 350 degrees Cent. the change is complete at the edge also and the zig-zags are now lighter colored than the matrix. Tempering in the sorbite range of martensitic steels produced a typical sorbitic structure for 600 and 700 degrees Cent., but precipitated cementite particles could not be resolved, with the microscope used, for 520 degrees Cent. At 700 degrees Cent. the needles and grain envelopes are broken up into strings of fine cementite particles and the zig-zags may be distinguished, but are again darker than the body of the specimen.

Besides etching in picric acid, the specimen as tempered at 350 degrees Cent. and at 700 degrees Cent. was etched in hot sodium picrate, Fig. 8 (a) and (b). Photomicrographs (c) and (d) of this figure are of the manganese steel quenched and tempered at 530 degrees Cent. and 800 degrees Cent. The needles developed in this steel on tempering at 530 degrees Cent. break up into round particles on higher tempering as do those of the austenitic carbon steel.

In order to obtain further evidence regarding the nature of the constituent assumed to be austenite, specimens quenched from 1000 degrees Cent. and 1080 degrees Cent. were polished and dipped in liquid air, Fig. 9 (a) and (c). The latter specimen was then etched, (d). Photomicrographs (b), (e) and (f) are the results of grinding off the roughened surfaces, polishing and etching. The effect of the liquid air treatment on the specimen quenched from 1000 degrees Cent. was slight, but the specimen quenched from the high-temperature showed deep roughening of the surface and fine white zig-zags in the matrix of the interior when etched which were developed to considerable size near the edge.

Identification of Constituents

The microstructure of the austenitic carbon steel appears complex, but the important constituents are easily identified. The assumption that the matrix of this steel is austenite is substantially justified by its characteristics. First, it has the simple polyhedral structure, neglecting the needles, of solid solutions. Second, twins are produced in it by cold deformation or simply by the quenching. Third, a buckling of the surface is developed on cooling to the temperature of liquid air and the microstructure revealed on subsequent etching is suggestive of martensite. Fourth, it is tough, for is displays slip-bands on cold deformation and does not crack from the radical quenching. Fifth, there is a decided change in the microstructure on tempering. It is immediately evident that these characteristics are common to austenitic alloy steels, but are not found in martensitic steels.

Westgren and Phragmen (18) furthermore show from X-ray spectrum analysis that a carbon steel of 1.98 per cent carbon content quenched in water from 1000 degrees Cent. and 1100 degrees Cent. is predominantly austenitic. A faint trace of martensite observed by them is evidently due to decarburization, which is present, as shown later, in specimens quenched from these temperatures.

Another easily recognized constituent is the free cementite found in all specimens except at the extreme edge. It appears in three forms: massive cementite, grain envelopes, and needles. The first two forms are readily distinguished by their contour, whiteness on acid etching and darkening on

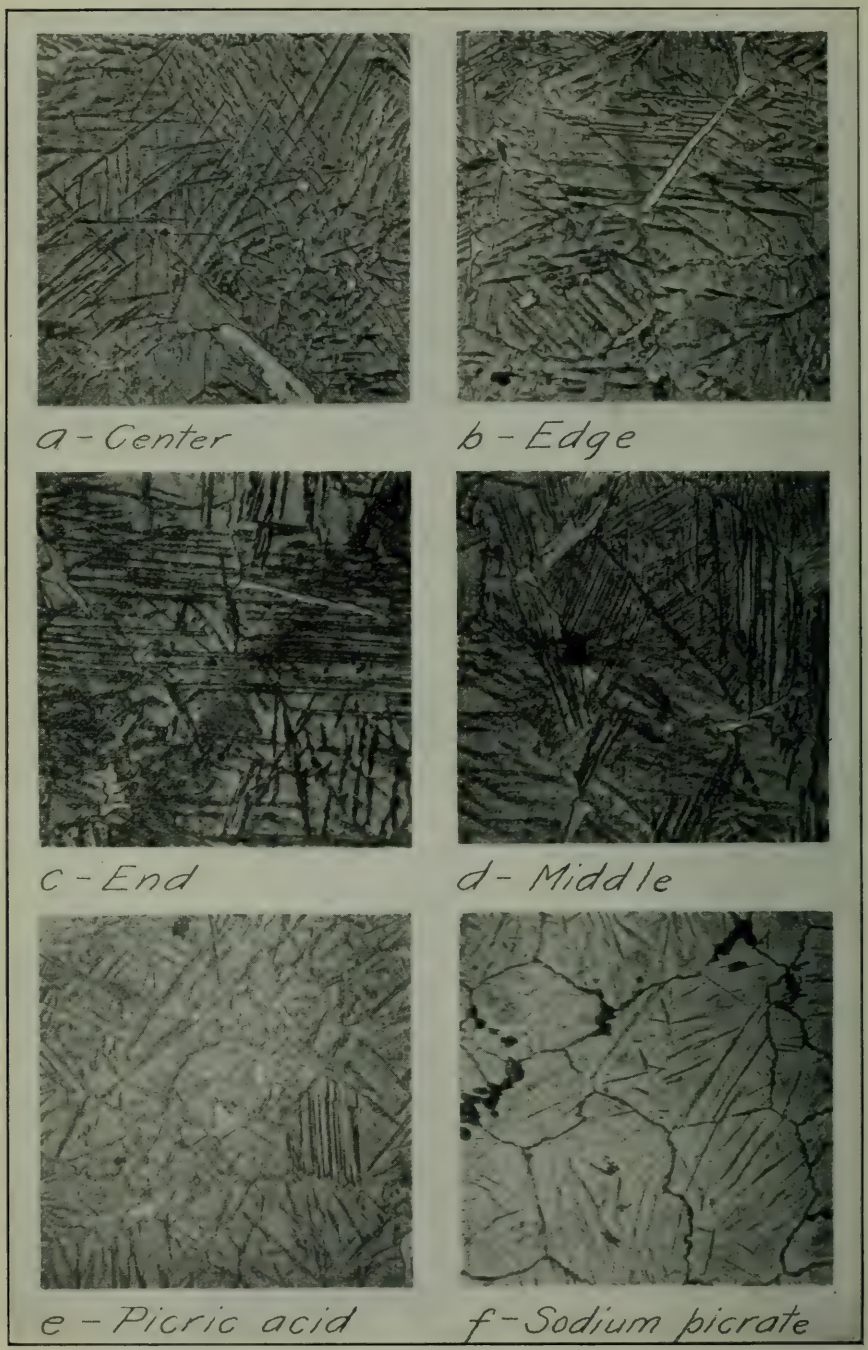


Fig. 4—Specimens of other shapes quenched in oil from 1080 degrees Cent. (a) and (b) sphere 0.55-inch diameter; (c) and (d), cylinder 0.30-inch diameter and 2 inches long; areas near surface of section at ½-inch from end, (c), and at the middle, (d); (e) and (f), interior of standard cylinder etched with picric acid, (e), and hot sodium picrate, (f). X 460.

sodium picrate etching, but the needles are somewhat confusing. These needles, plates in three dimensions, appear dark on acid etching as they are very thin and etch in relief, but have a white backbone when in focus. They also connect with cementite grain envelopes, darken on sodium picrate etching and spheroidize on tempering as is characteristic of cementite. These cementite needles evidently separate from the solid solution saturated at 1080 degrees Cent. for they are not present in the original structure. The austenite must then contain in solution at ordinary temperatures less than the amount of carbon dissolved at 1080 degrees Cent., that is, less than about 1.6 per cent. The absence of free cementite near the surface after high-temperature heating shows that decarburization has occurred there and this is probably responsible for the structural zones. On the other hand the closely packed cementite plates in the interior probably prevent the formation of twins there.

A third constituent referred to as zig-zags is found near the edge of specimens quenched from the high temperature. The constituent appears first, moving from the center toward the edge, when the area free from long cementite needles is reached and becomes more abundant as the edge is approached finally merging with the martensite shell, Fig. 2. Lighter, but otherwise similar, zig-zags are formed in the austenite when dipped in liquid air and in this case are unquestionably martensite. It is also highly probable that the dark zig-zags are martensite for tempered to sorbite they contain fewer cementite particles than the body of the specimen as noted by Haneman (3) and confirmed here.

The constituents of tempering an austenitic carbon steel are evidently continuous with those of a martensitic steel except that the formation of troostite proceeds in two stages. This change must be completed just above 250 degrees Cent. in the interior of the specimen according to the micrographs, for the transformation proceeds at an increasing rate with temperature. This agrees exactly with the evidence from heating curves of an austenitic carbon steel (5) which show the change is completed at 260 degree Cent. for a very slow heating rate. Martensitic steels are completely decomposed to troostite at the same temperature which indicates that the austenite transforms to martensite before decomposing to troostite and this is verified by the changes in physical properties accompanying tempering, page 554 of the above reference.

Critical Cooling Rate

A significant feature of the cooling rate experiments leading to the production of troostite in an austenite matrix is the very slow cooling rate at which austenite was obtained. Previous expressions of the conditions necessary for the retention of austenite in carbon steels state that a very fast cooling is required besides a high temperature and carbon content. However, austenite was produced inside a martensite shell and therefore at a slower cooling rate than the martensite, the essential difference being that of carbon content. It was also produced with a cooling rate much slower than that required normally to produce martensite, namely, air cooling. For the high quenching temperature there was no constituent found intermediate between austenite and troostite so the determining factor as to whether austenite or martensite will be had at ordinary temperatures is not the cooling rate, so long as it is fairly fast, but the temperature, or, generally stated, the amount of carbon retained in solution.

The critical cooling rate for the retention of austenite, that is, the slowest cooling rate at which austenite can be retained without troostite forming, is

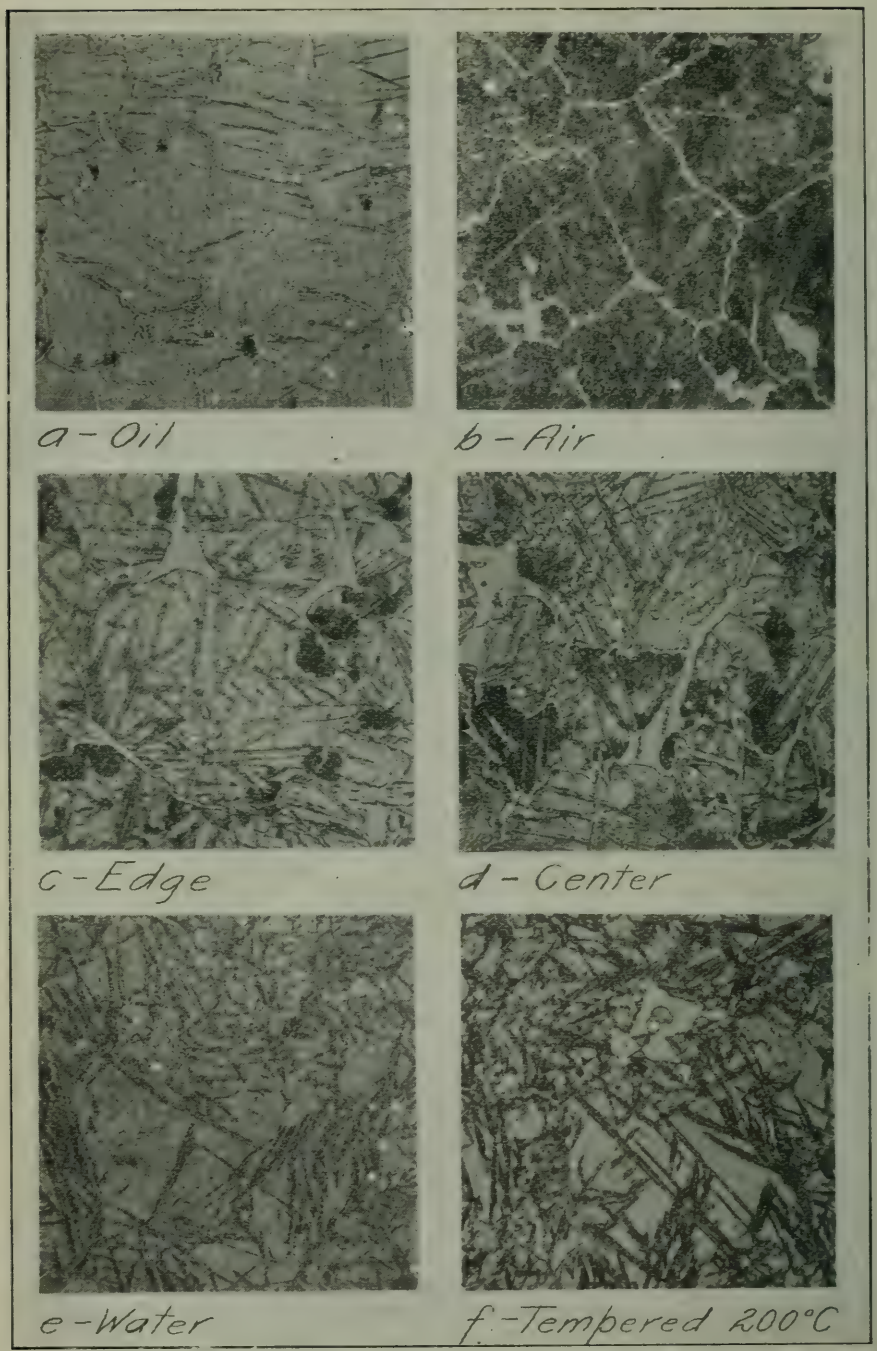


Fig. 5—Cylinders of steel A cooled from 1080 degrees Cent. at different rates; (a), 5/8-inch diameter quenched in oil; (b), 1/2-inch diameter cooled in still air; (c) and (d), 1/4-inch diameter cooled in mild air-blast; (e), 1/2-inch diameter as quenched in water and (f) same tempered at 200 degrees Cent. X 465.

obviously much slower for austenitic carbon steels than for martensitic carbon steels. This phenomenon is explained, at least in part, by the experiments on martensitic carbon steels described in the following section.

Macro and Microstructure of the Martensitic Steels

The most striking feature of the martensitic steels is the distribution of quenching troostite in the presence of martensite. To reveal it the specimens were sectioned as before and etched with 5 per cent nitric acid in methanol, which reagent produces better contrast between the constituents under examination than picric acid. The entire sections were then photographed at a magnification of 4 diameters and are reproduced in Figs. 10 and 11.

The effect on the B steel of varying the cooling rate from 1080 degrees Cent. by the use of different cooling media is shown in the first four pictures of Fig. 10. The black constituent is of course troostite of quenching and the white martensite. The fastest quenching, (a), produced a section the majority of which was martensitic, but with a quarter-moon of troostite on one edge. The next less drastic quenching, (b), resulted in two crescents of noncontinuous martensite on opposite edges and some small patches in the center. Oil quenched specimens, (c) and (d), contained a few small spots of martensite in the central portions only. The results of water quenching from 960 degrees Cent. and 800 degrees Cent. are shown in (e) and (f) respectively. Martensite occupies about half the area and one side only of the former, but less than half of the latter taking the shape of two opposing crescents concave inward. In no case does the martensite completely enclose the troostite as a continuous rim unless the specimen be vigorously stirred, Fig. 11 (a). Quenching in oil from 800 degrees Cent. produced no martensite, Fig. 11 (b).

As is commonly known, a steel near the eutectoid composition hardens deeper than higher carbon steels. Steel C illustrates this. A mild water quench from 1080 degrees Cent., Fig. 11 (c), produced martensite over the whole section except at the extreme edge where troostite is visible only at higher magnifications. The gray curved bands in this macrograph and also the dark spot in the martensite at the bottom of Fig. 10 (f) are not the black troostite of quenchings, but merely reddish-brown areas in the martensite which photograph dark. Quenching in oil also produced martensite over the whole section, Fig. 11 (d), but it takes the form of a discontinuous aggregate cemented by troostite. The troostite forms only grain envelopes in the outer portions, but is more concentrated near the center. Water quenching from 800 degrees Cent. also resulted in the formation of martensite throughout the section, but it is interspersed with troostite in the central region. Quenching in oil from the same temperature, however, failed to produce any martensite, Fig. 11 (f).

The microstructure of some of these specimens also shows noteworthy features. Fig. 12 gives the structure of the B steel as quenched from 1080 degrees Cent., (a), (b) and (c), and of the same specimen polished, dipped in liquid air and then etched, (d), (e) and (f). There was no roughening of the surface developed by the liquid air treatment, but the martensite needles etch in bolder relief. In Fig. 13 are shown the results of water quenching from 960 degrees Cent., (a), (b) and (c) and from 800 degrees Cent., (d), (e) and (f). These correspond to the macrographs of Fig. 10, (e) and (f), respectively. There is considerable free cementite after the 800 degree Cent. quench, but none following the higher temperature quenches.

A spot of the martensite in the center of the B steel as quenched in oil, macrograph of Fig. 10 (c), is shown in Fig. 14 (a) and (b). An acicular

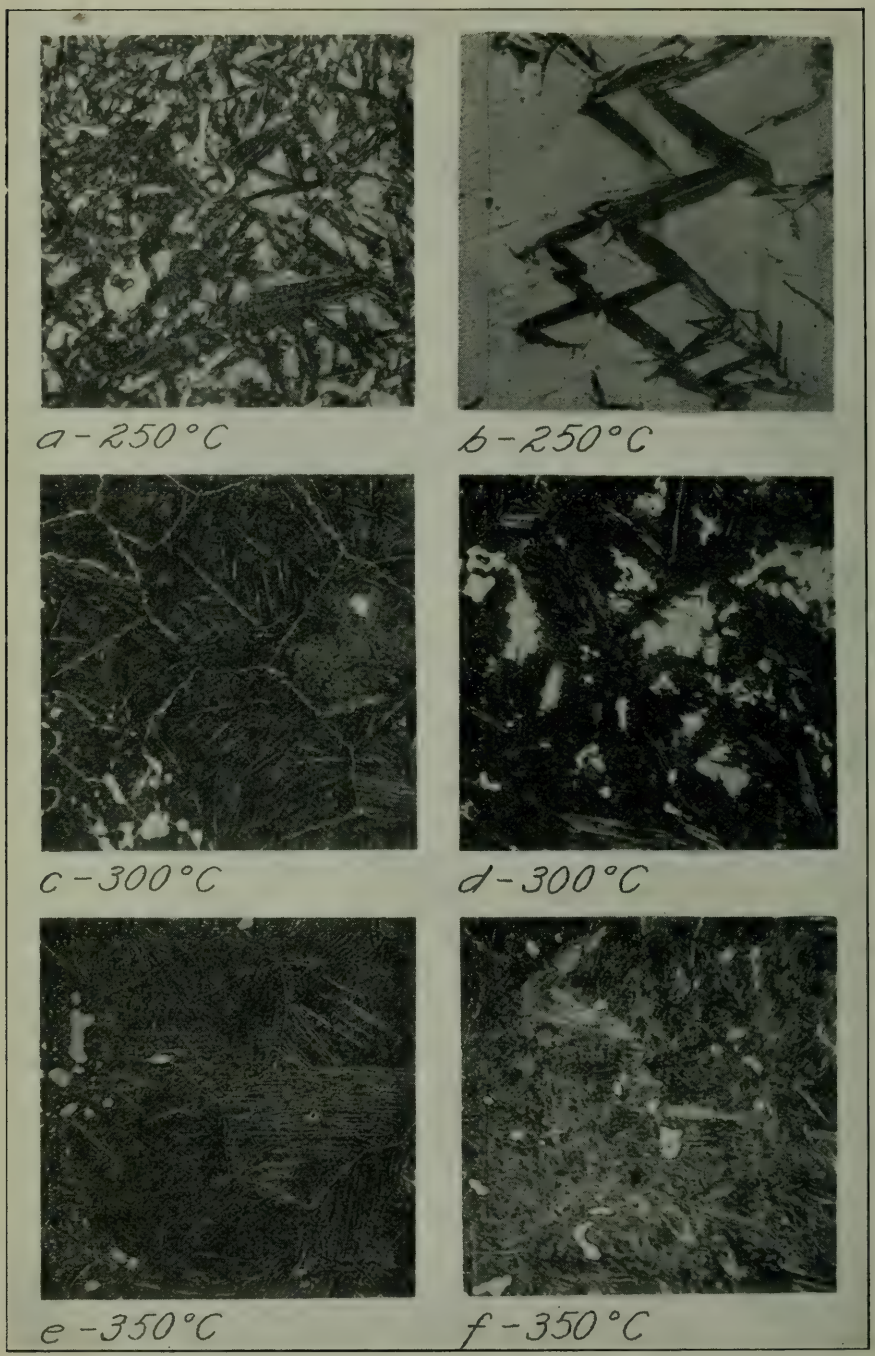


Fig. 6.—Steel A quenched in water from 1080 degrees Cent. and tempered at the temperatures noted. (a), (c) and (e) are structures typical of the center and (b), (d) and (f) of areas near the edge. X 460.

structure is developed, but it does not have the contrast of that produced by faster cooling.

The microstructure of different areas of the C steel, the macrostructure of which is given by Fig. 11 (c), is shown in Fig. 14, (c), (d) and (e). The dark lines of (c) are evidently cracks outlining the grains. Photomicrograph (d) of this figure shows the typical structure of the main body of the specimen and (e) that of the extreme edge. The troostite shown here only extends to the depth of a few grains. The same steel quenched in water from 800 degrees Cent. furnished the familiar structure of Fig. 15 (a) and (b).

Troostite Formation in the Martensitic Steels

The distribution of troostite in the martensitic steels is quite different from what might be expected according to the general impression that rate of cooling alone determines where it will be formed. This conception, however, neglects a very important variable in phase relations, namely, stress. Since a body cannot be heated or cooled without the development of temperature gradients and a temperature gradient produces stress in any body having a definite expansivity and elasticity, it is evident that stress is an ever present factor in the heat treatment of steel. Obviously, then, there are three factors which enter into this problem, namely, the transformations, the cooling rate distribution, and the stresses present in cooling steel. In regard to troostite formation, however, the status of stress is important only at the time of transformation.

The Transformations in Cooling Steel

The transformations occurring in cooling steel have been extensively studied in recent years and the effect of the most important variable, rate, has been definitely established. The significant facts are most concisely presented in the form of idealized curves, Fig. 16. Here Ar′ is the familiar eutectoid transformation at which austenite transforms on slow cooling into pearlite or its equivalent in alloy steels. Ar″ is the lower temperature transition of austenite to martensite and Ar′ is the continuation of Ar_1 for rates at which troostite forms from austenite. Between the cooling rate limits A and B both Ar′ and Ar″ occur if the steel be cooled to a low enough temperature. The cross-hatched areas indicate the variations in intensity of the respective transformations and between A and B show the relative proportions of the final constituents, troostite and martensite, or austenite if Ar″ is below normal temperatures.

This generalized diagram applies to the areas of eutectoid composition, but is easily modified to fit any particular steel. Of special interest here is the effect of free cementite which dissolves and lowers Ar″ as the quenching temperature is raised. If sufficient carbon be held in solution, Ar″ will be depressed below ordinary temperatures and the steel will then be austenitic, for example, steel A quenched from the high-temperature.

The information on which this diagram is constructed is contained with further references in several previous papers (6, 7 and 10). The nomenclature used, with the exception of the distinction between Ar′ and Ar_1, is that of Portevin. This distinction, as expressed by the figure, is justified by the fact that Ar_1 is abrupt and Ar′ continuous (10) and (11), so the maximum of the latter must be lower than the former even if both start at the same temperature.

An important ordinate on the cooling rate diagram is that of the critical

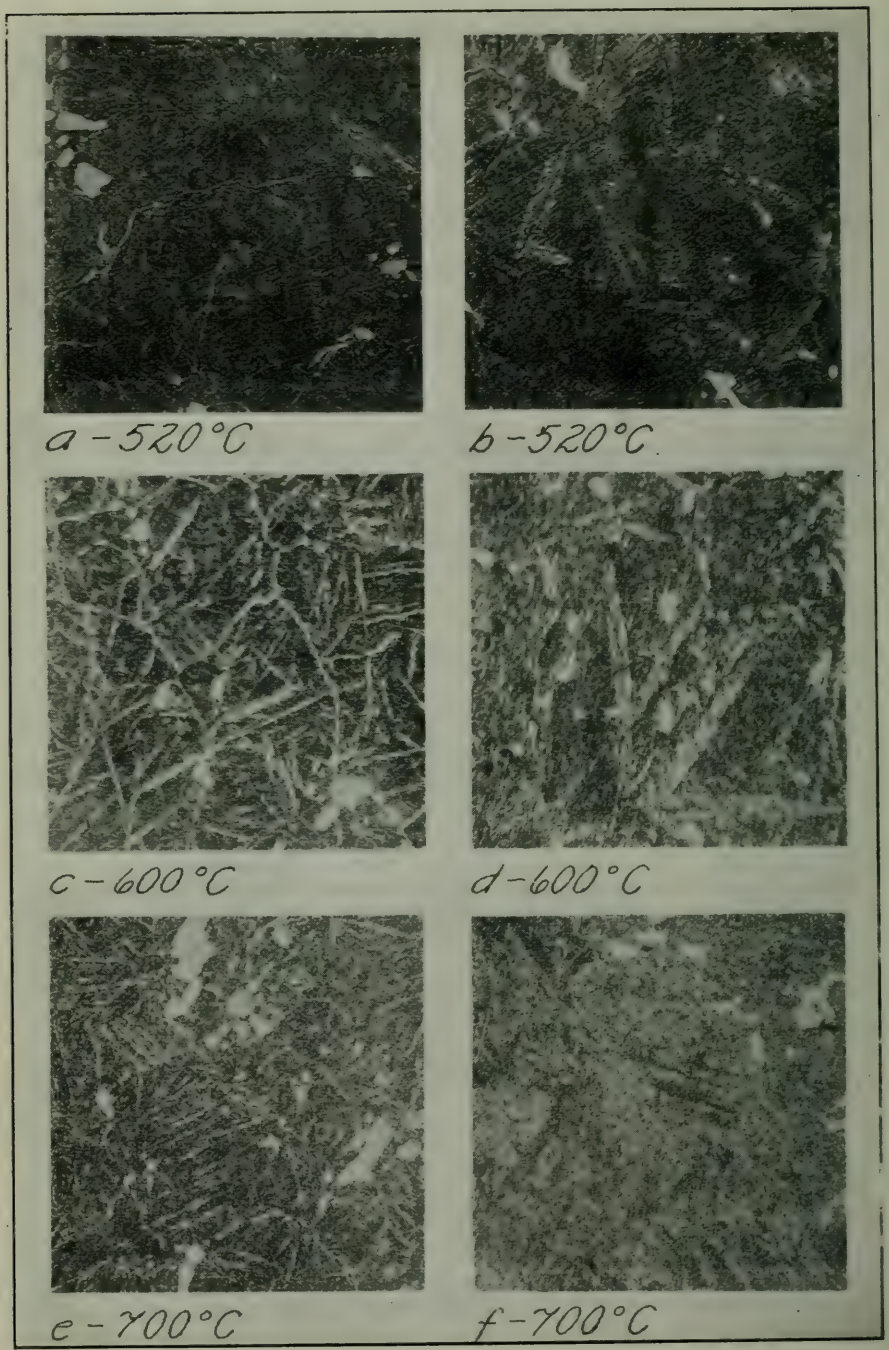


Fig. 7.—Same specimen as Fig. 6 tempered at higher temperatures. (a), (c) and (e) are structures typical of the center and (b), (d) and (f) of areas near the edge. X 465.

cooling rate, generally defined by the point B of Fig. 16, that is, the slowest cooling rate at which the steel can be obtained purely martensitic or austenitic. This definition is satisfactory for steels hardening with slow cooling rates in which case no serious thermal stress is developed. However, if quenching is resorted to considerable stress may be developed which will displace the position of the critical rate ordinate. This requirement of low stress is not met in Portevin and Garvin's quenching curve experiments so the critical values obtained by their method or similar methods will be referred to as apparent critical cooling rates.

Fig. 16 shows that Ar″ occurs only in the austenite which has not undergone transformation at Ar′ so the final pattern is determined by the latter change. The effect of rate of cooling and of stress is then significant only as existing in areas undergoing this transformation which, in carbon steels, occurs in the neighborhood of 650 degrees Cent. One should then consider the rate distribution at this temperature rather than at a given time.

The Cooling Rate Distribution on Quenching

The temperature distribution in slowly cooling bodies is practically uniform so the rate is constant over any section, but it is not so simple in rapidly cooling bodies. It is in fact very difficult to determine experimentally the time-temperature curves for any position in bodies undergoing quenching, and the only accurate information from this source is that for the center of steel cylinders. The problem is, however, susceptible of mathematical analysis from which the desired information may be obtained. It is assumed that the surface of a simple shaped body is cooled immediately to some final temperature at which it is maintained. This is obviously the fastest rate at which the body can be cooled and one hardly possible to attain, nevertheless drastic water quenching approximates it fairly closely and according to McCance (14) the calculated cooling curves for the center of cylinders agree well with the observed curves for temperatures above Ar′. As has already been pointed out, this is the significant region of the curves.

The theoretical cooling rate distribution along a radius of a sphere is given by the slope of the time versus temperature ratio curves presented by Heindlhofer (15) and reproduced in Fig. 17. These generalized curves hold for any quenching temperature and size of sphere so long as the time ordinate is increased as the square of the radius. A similar family of curves could be constructed for long cylinders and in that case the cooling for the same diameter would be slower, but the curves would have the same relative slope at any temperature. The cylinders used are intermediate between these two cases, but since the information desired is relative only, either case will serve.

Fig. 17 shows clearly that the cooling rate at a given temperature is much faster at the edge than in the center and that its distribution is much more uniform near the center than near the edge. The effect of quenching temperature on the rate at the temperature of Ar′ is, however, more clearly shown by plotting the temperature at the center and at a point 1 millimeter from the edge against time for the two extreme quenching temperatures used here, Fig. 18. These curves show the rate at the center to be faster for the higher quenching temperature than for the lower, but the rate gradient between center and edge is greater with the lower quenching temperature. In regard to the effect of quenching temperature on the rate at the center, McCance (14)

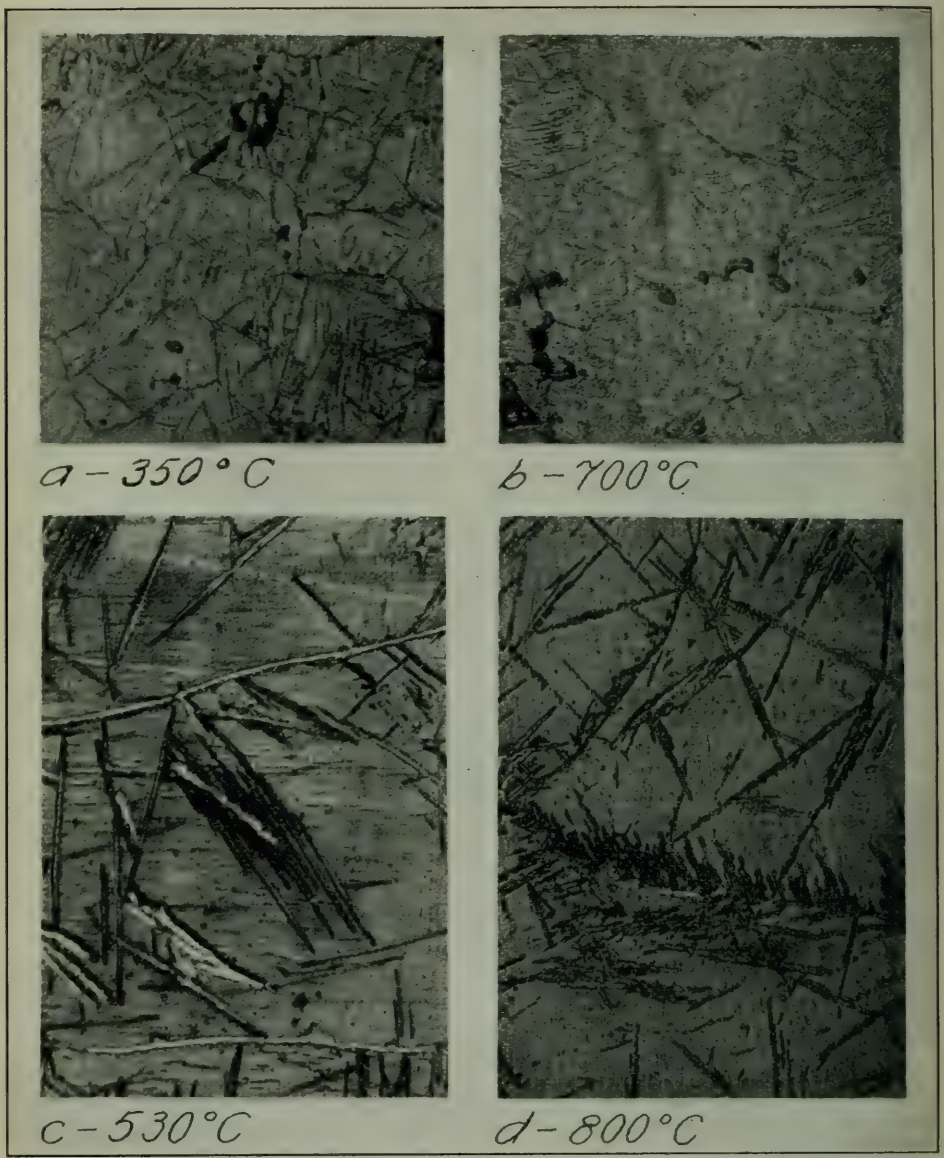


Fig. 8.—Tempered austenitic carbon and Hadfield manganese steel. (a) and (b), steel A etched in hot sodium picrate; (c) and (d), manganese steel. Both steels were quenched in water from 1080 degrees Cent. and tempered as noted. X 500.

shows that the increase at a given temperature becomes slower the higher the quenching temperature and is negligible over 1000 degrees Cent.

The Stress in Steel During Quenching

Since the distribution of troostite is determined by Ar′, the effect of stress on that change is of immediate interest. This transformation occurs with an increase in volume so, according to LeChatelier's principle, pressure

will lower the temperature at which it occurs and tensional stress raise it. Lowering this transformation represses it so pressure must restrict troostite formation and tension favor it. Portevin and Garvin (6) assume the reverse, but do not give the basis for this assumption. They argue on that assumption that a small diameter rod will have a faster critical cooling rate than a larger one and cite the dilatormetric observations of Chevenard (8) as evidence. It is, however, probable that the fine wires of Chevenard were under tension to keep them taut and this would explain the high value of the critical cooling rate obtained.

The sign of the stress in rapidly cooling steel cylinders, that is, whether tension or compression, is evident from a consideration of their temperature distribution and the well-known physical properties of steel. This subject has been treated at length by Tafel (12) and the significant points only are mentioned here. Steel heated to a high temperature is practically free from stress for its elastic limit is then very low and pre-existing stresses will plastically deform the body, thus disappearing. If the body is now plunged in a liquid, the surface will quickly assume a much lower temperature than the center. At this stage the core will have a greater unit volume than the colder shell and so be under compression while the latter is in tension. The elastic limit cold is exceeded for even small temperature gradients according to Wille (13) so, since the metal is practically incompressible, the shell will be plastically stretched to conform to the core. As the interior cools to the same temperature as the shell it will also shrink, but since the shell has assumed a greater volume than normal, the stress gradient will reverse leaving the shell in compression and the core in tension. This is the condition before Ar″ is reached in the center, but it may be greatly modified by that change. However, the final stress distribution has no bearing on the present issue.

Since the thermal stresses are produced by temperature gradients, a conception of their relative magnitudes under several conditions may be had by again referring to the temperature distribution in cooling bodies. The curves of Fig. 17 show that at any time the gradient between center and edge is greater near the edge than near the center, that is, the stress is a maximum at the edge. From Fig. 18 it may be noted that the gradient is greater the higher the quenching temperature. It is also evident that a very large temperature difference exists between the center and the surface when the center reaches Ar′, about 450 degrees Cent. on quenching from 800 degrees Cent. for the conditions assumed in Fig. 18.

From this analysis the the effect of extremes in the most important variables of quenching, rate of cooling, and initial temperature, on the rate and stress distribution may be stated as follows. If the cooling rate be very slow it will be uniform over any section and no appreciable stress will be developed, no matter what the initial temperature may be. If the cooling rate be that of a very drastic quench, it will be much faster at the edge than at the center, but the difference in rate between center and edge will be less for a high quenching temperature than for a low. A high quenching temperature also causes a faster rate at the center and greater stress than a low one.

The Effect of Stress on the Distribution of Troostite

In the experimental data each of the cases of extremes in cooling rate and quenching temperature shows a characteristic stress effect traceable also

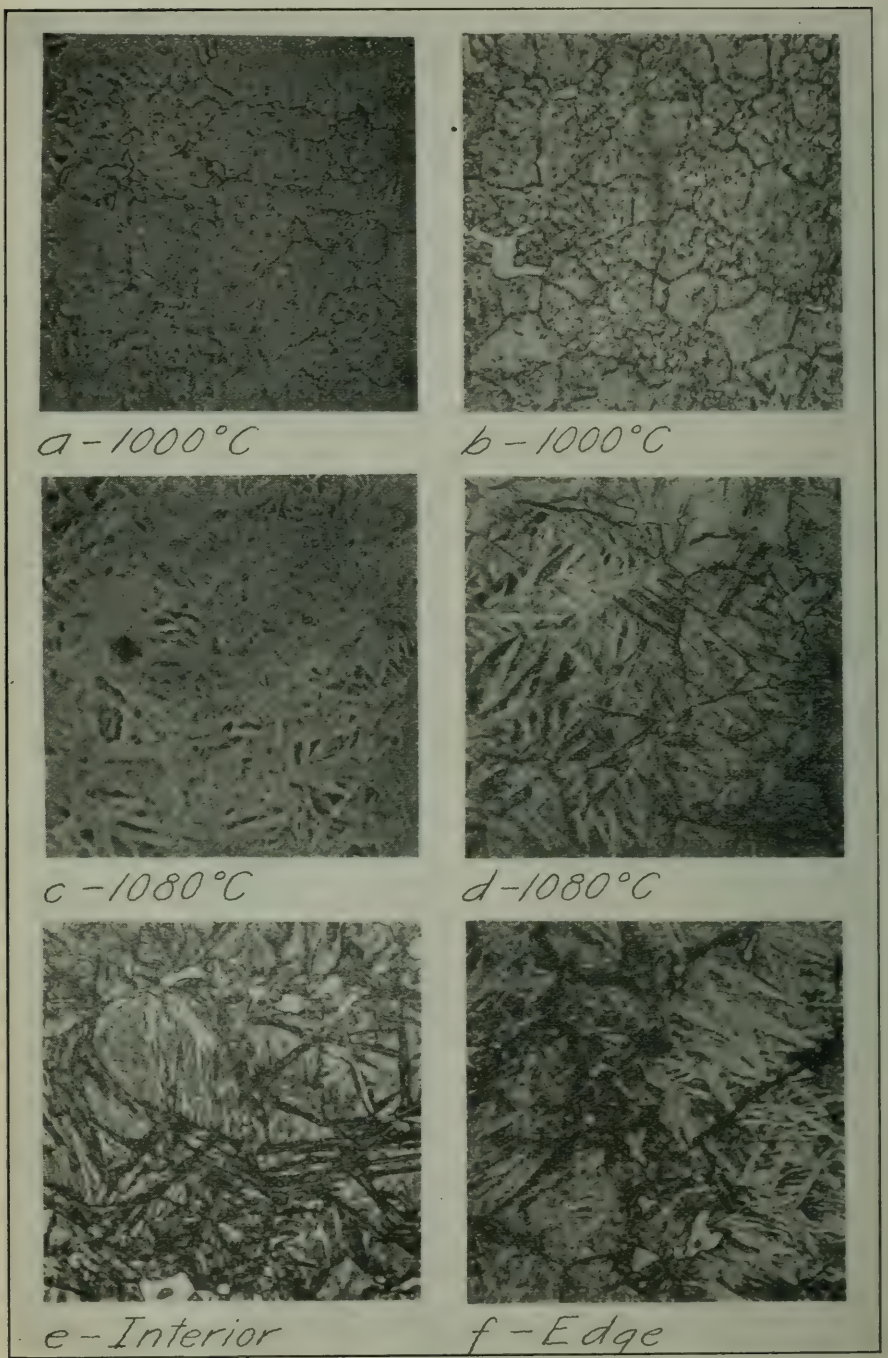


Fig. 9.—Steel A dipped in liquid air after water quenching from 1000 and 1080 degrees Cent. (a), (c) and (d), structures developed on faces polished prior to immersion in liquid air; (b), (e) and (f), repolished and etched after liquid air treatment. X 460.

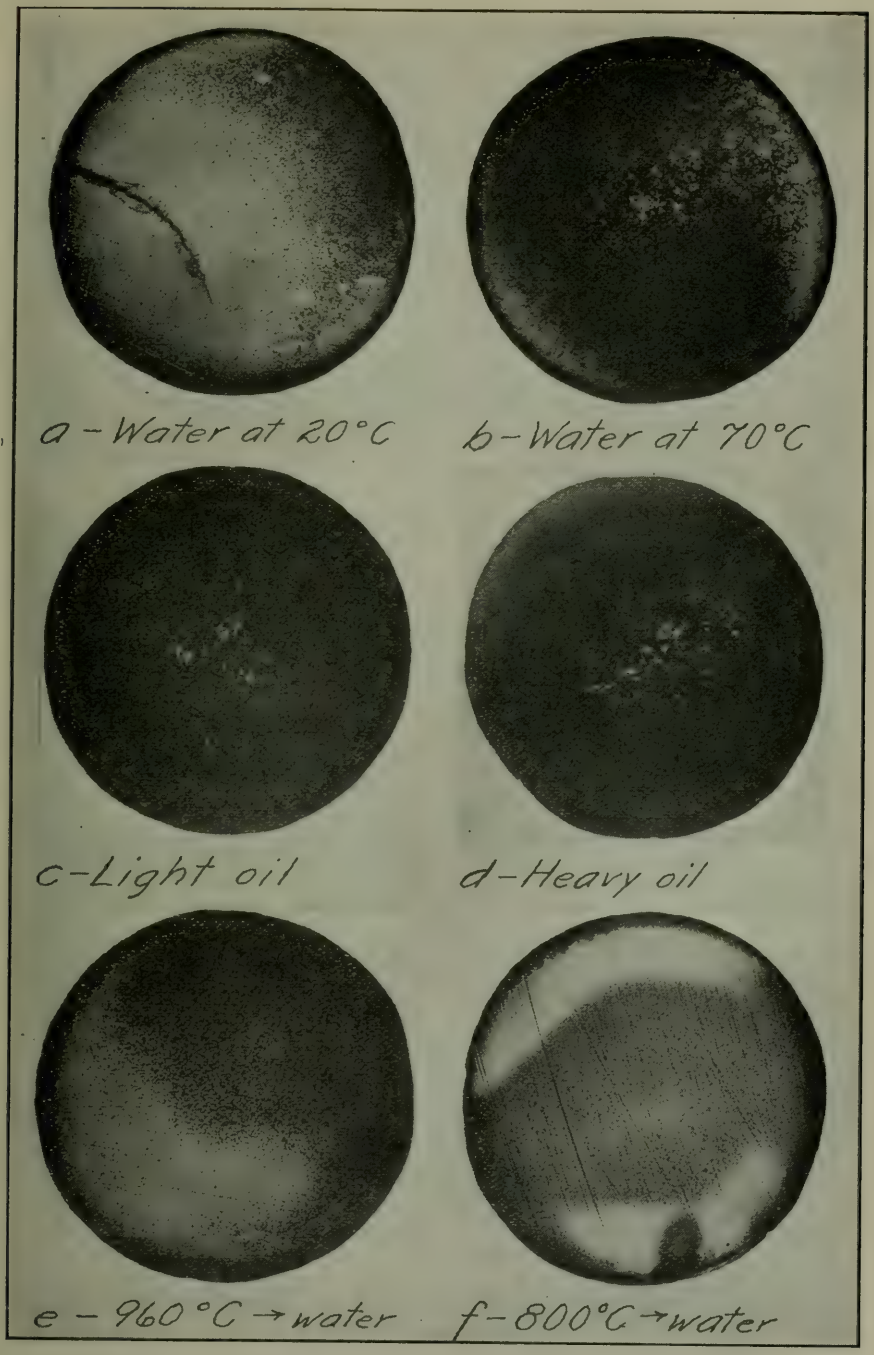


Fig. 10.—Effect of quenching temperature and medium on the distribution of troostite in a martensitic steel. Sections of steel B magnified 334 diameters. (a), (b), (c) and (d), quenched from 1080 degrees Cent. in medium indicated; (e) and (f), quenched in water from 960 and 800 degrees Cent. respectively.

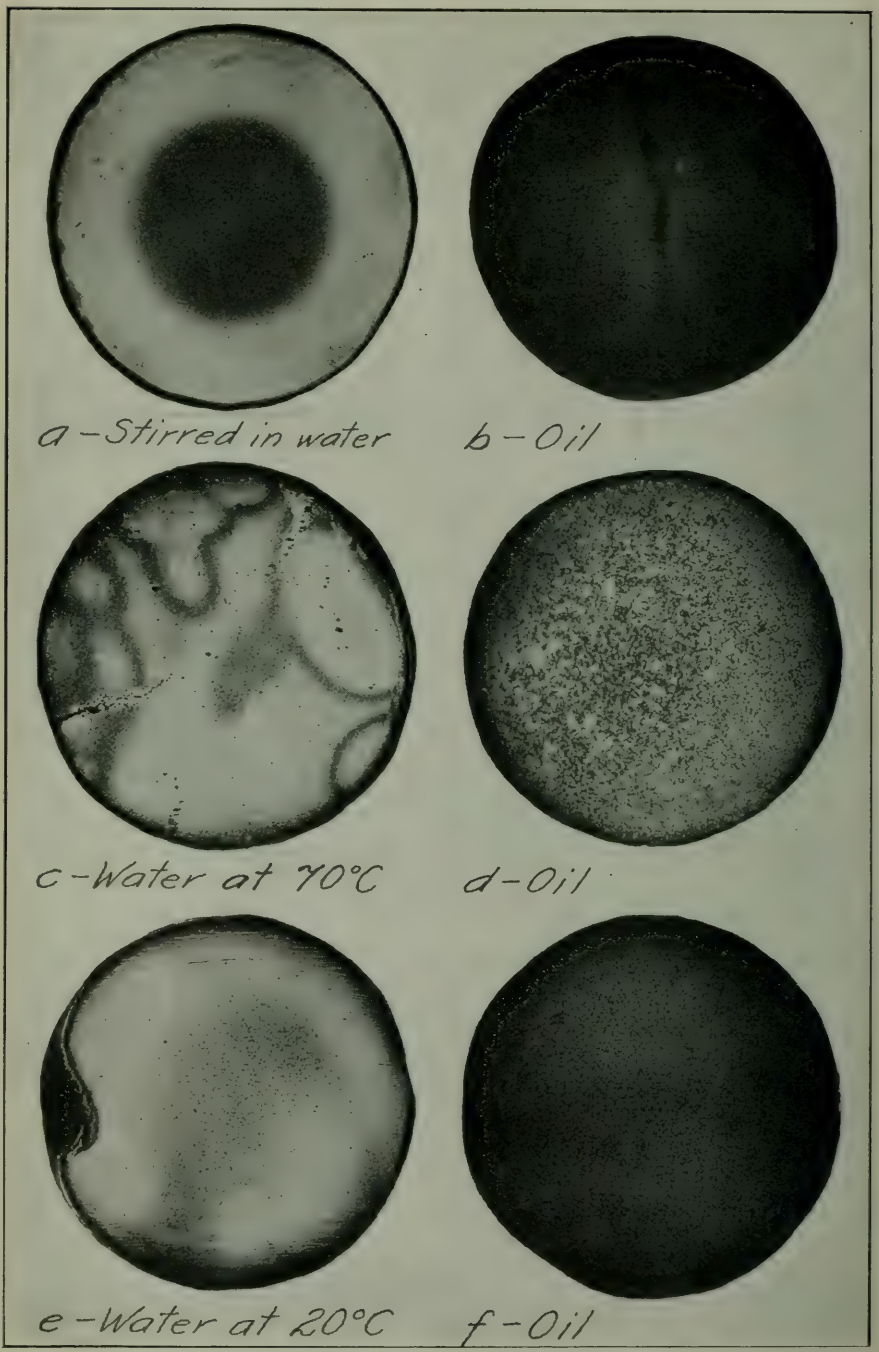


Fig. 11.—Effect of quenching on troostite distribution in martensitic steels. (a) and (b), steel B quenched from 800 degrees Cent.; (c) and (d), steel C quenched from 1080 degrees Cent.; (e) and (f), steel C quenched from 800 degrees Cent. Magnification 3¾ diameter.

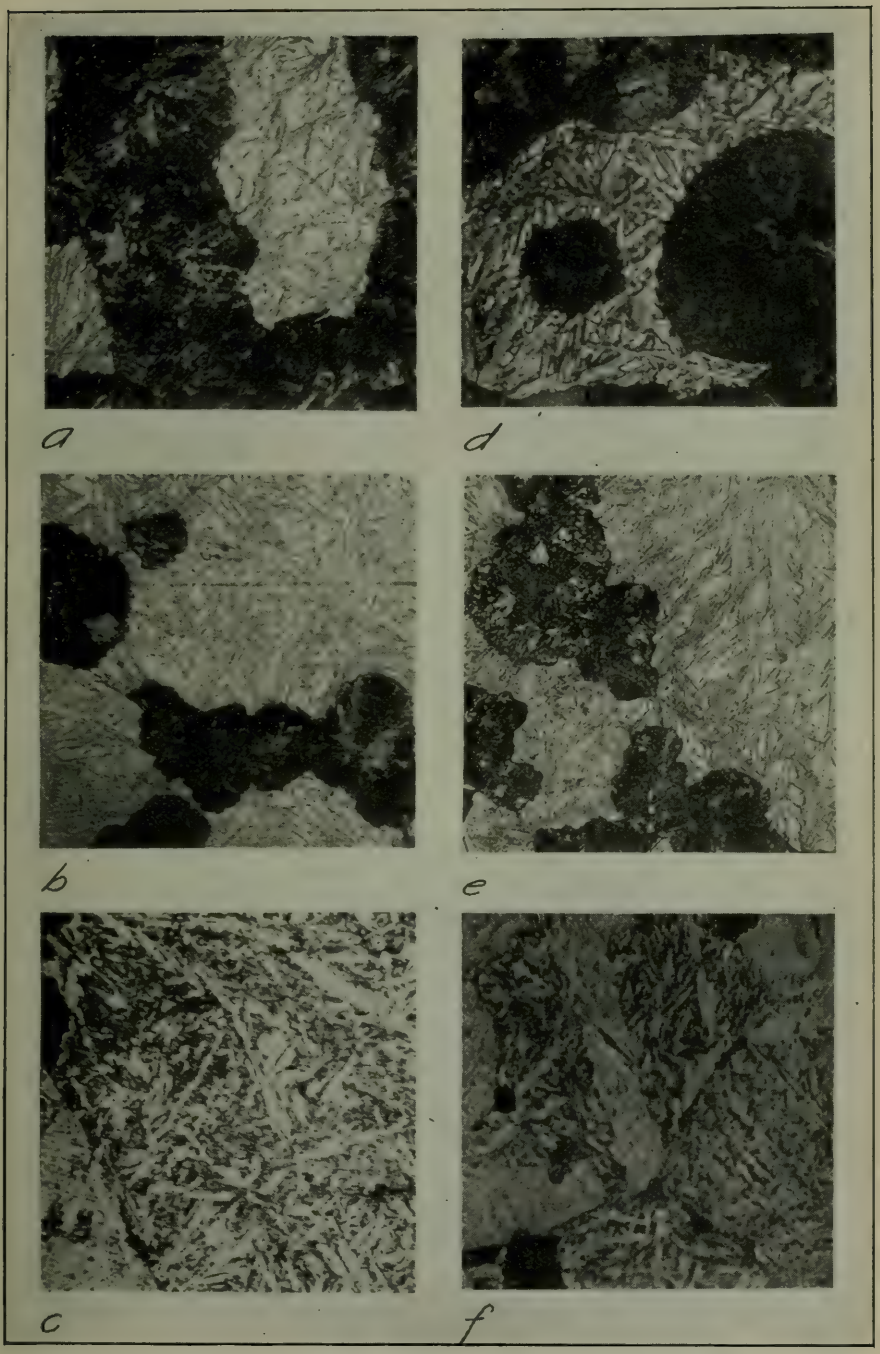


Fig 12.—Microstructure of steel B quenched in water from 1080 degrees Cent. (a), (b) and (c), as quenched; (d), (e) and (f), same polished, dipped in liquid air and etched. X 460.

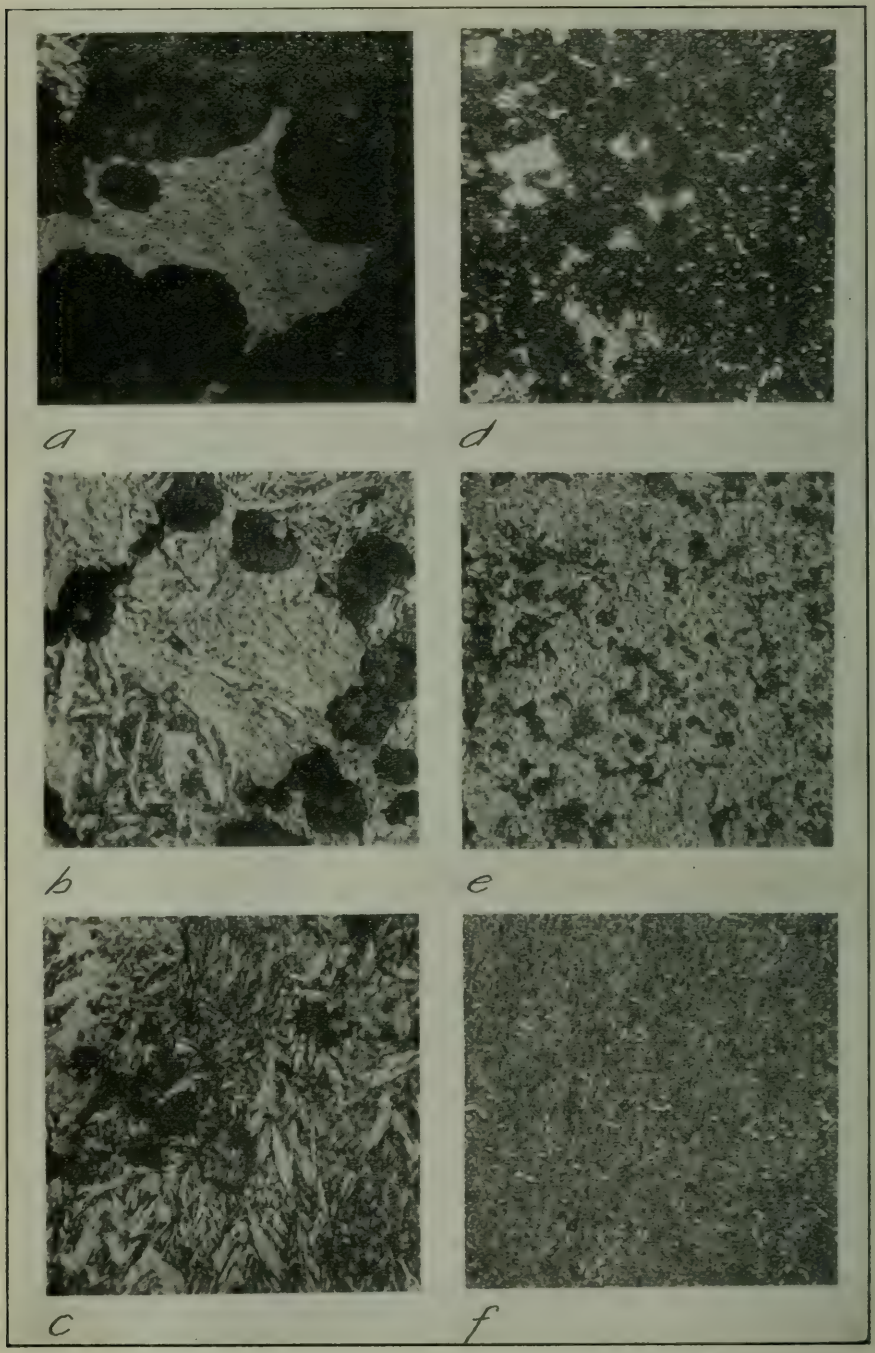


Fig. 13.—Microstructure of steel B quenched in water; (a), (b) and (c), from 960 degrees Cent.; (d), (e) and (f), from 800 degrees Cent. X 465.

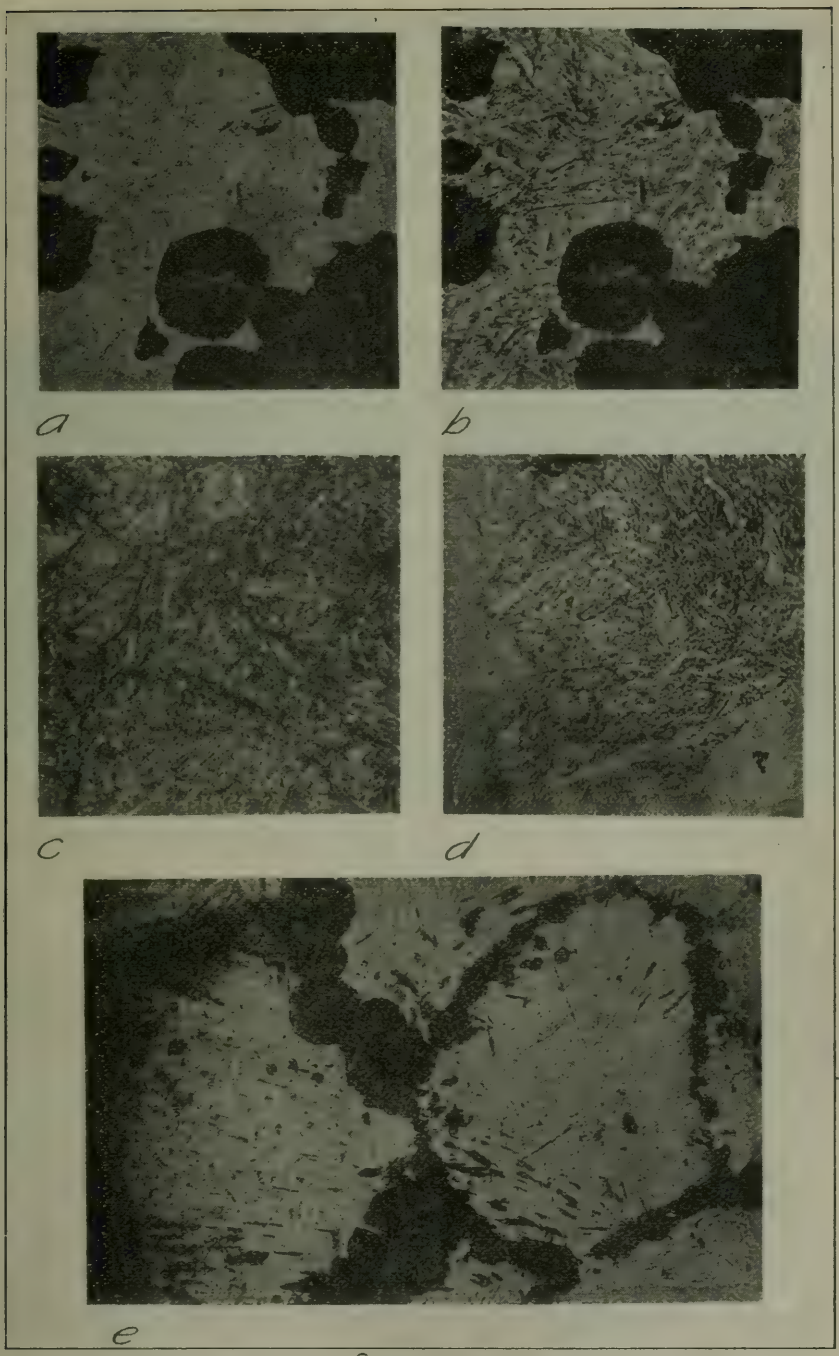


Fig. 14.—Microstructure of steels B and C. (a) and (b), martensite spot in center of specimen of steel B quenched in oil from 1080 degrees Cent.; (c), (d) and (e), steel C quenched in water at 70 degrees Cent. from 1080 degrees Cent. X 445.

in the several intermediate treatments. Take first the case of the austenitic carbon steel containing uniformly distributed troostite in austenite after cooling in a mild air-blast, Fig. 5 (c) and (d). Evidently the stress was low and the cooling rate quite uniform. The troostite was accordingly distributed as required by the cooling rate alone and so was necessarily uniform which is the condition essential for determining the true critical cooling rate of the steel.

The critical cooling rate of the austenitic carbon steel is much slower than the apparent critical cooling rates of martensitic steels quenched from the same temperature. The reason for this difference between the austenitic

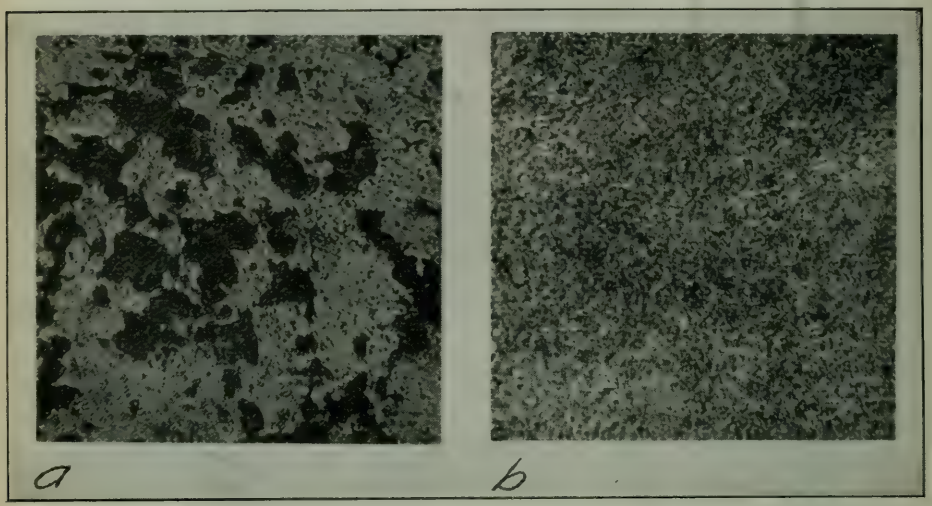


Fig. 15.—Microstructure of Steel C quenched in water from 800 degrees Cent. X 500.

and the martensitic steels is not the final state of the matrix, for the troostite forms from austenite in either case. It is probably due to a small decrease in the critical cooling rate with lowered carbon content which demands quenching and its accompanying stress effects favorable to troostite formation.

The effect of quenching stresses in abetting the formation of troostite is shown by the martensitic steels quenched from 1080 degrees Cent., the condition for maximum stress when Ar′ is reached. Thus a specimen of steel C was uniformly martensitic except for a fringe of troostite adjoining the surface, Fig. 11 (c) and 14 (e). The critical cooling rate was obviously exceeded throughout the whole specimen, but the tensional stress on the surface was more than sufficient to neutralize the effect of the fast rate there and so to allow troostite precipitation. The same effect is predominant with much slower cooling rates. Specimens of steel B quenched in oil, Fig. 10 (c) and (d), had martensite in the center alone, the remainder being troostite. In this case the cooling rate was evidently near the critical value and more uniform across the section than before so the peripheral tension was sufficient to cause troostite formation in the outer layers, while the reacting pressure in the center partially suppressed that change there.

The other extreme in quenching temperature, 800 degrees Cent., reduces the stress, but does not eliminate it and causes a greater difference in

cooling rate between center and edge than the higher quenching temperatures. Thus in steel B quenched in water without agitation, the martensite was all near the surface, but was broken by troostite areas at two opposite points, Fig. 10 (f). The surface troostite is evidently due to circumferential stress and is only eliminated when the specimen is agitated in water, Fig. 11 (a), thereby cooling rapidly enough to exceed the critical cooling for that stress.

It is probable from previous considerations that the critical cooling rate of these specimens was exceeded near the center also. Quenching in water from

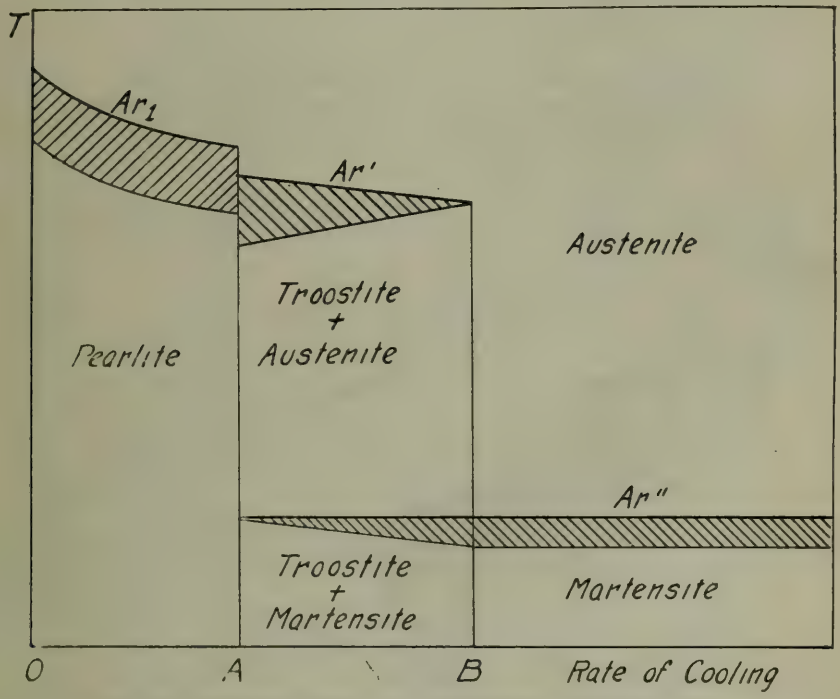


Fig. 16—Generalized diagram of transformation in cooling steel.

800 degrees Cent. certainly creates as fast a cooling rate as the center when Ar′ is reached as quenching in oil from 1080 degrees Cent. Pressure must have existed there also so troostite could hardly be expected to form in the center. There is, however, another element which enters here, namely the expansion of martensite forming at Ar″. The expansion of the hard martensite forming on the surface may easily reverse the stress in the interior from compression to tension while it is still above Ar′ thereby affording opportunity for troostite to form there. A sufficiently large temperature gradient for this to occur is quite possible as Fig. 18 shows. This effect is not present on quenching from the high temperature for Ar″ is then lower and consequently is not reached in the outer layers until a much later time. Fig. 19 taken from the dilatometric quenching experiments of Honda (9) shows Ar″, the inflection in the cooling curve, lower for a high quenching temperature than for a low one in a hypereutectoid steel and also the considerable expansion accompanying this change. Portevin and Garvin (6) observe Ar″ at the center of specimens, quenched in a manner to produce a peripheral layer of martensite, several seconds later than Ar′. This, however, does not prove

that the two transformations do not start at the same time, as required by the above view, for an appreciable time is required for the heat wave generated by Ar″ to travel through the specimen to the center where the thermocouple is situated.

The macrographs for other treatments show various combinations of the effects observed independently in the above extreme cases. Thus all the specimens of steel B quenched from 1080 degrees Cent., Fig. 10 (a), (b), (c), and (d), show martensite in the center and troostite at the edge, the to-

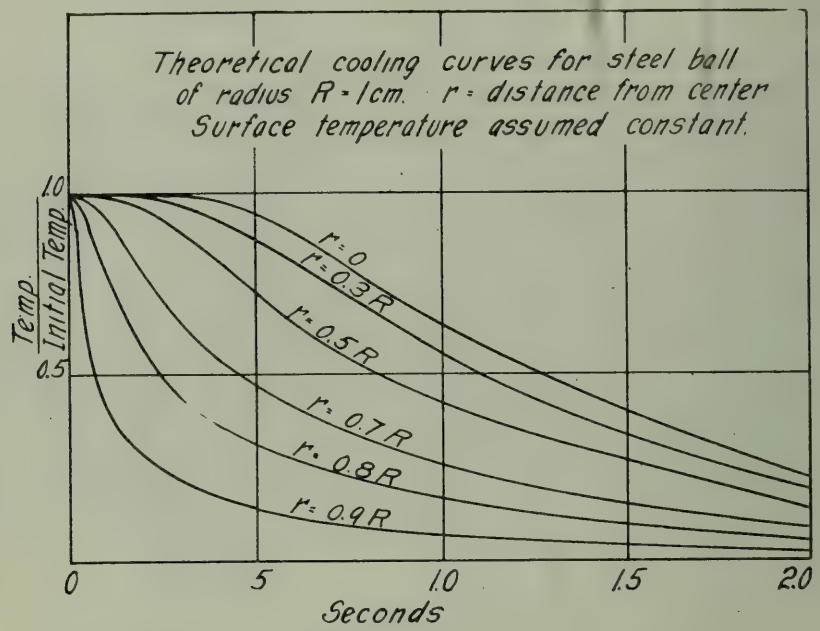


Fig. 17.—Theoretical quenching curves of a steel sphere.

tal amount of martensite of course decreasing with lowered cooling rate. This distribution is predominant with oil quenching for the rate is then more uniform across the section. The appearance of the crack in the martensitic area of Fig. 10 (a) indicates that it occurred at a high temperature. In this case the tension in its neighborhood may have been relieved when Ar′ was reached, preventing troostite formation there.

With decreasing quenching temperature, Fig. 10 (a), (e), and (f), the ratio of martensite to troostite does not change as much as might be expected from the corresponding change in the rate at the center, but the change in position of the troostite areas is very marked. This shows the effect of the sharper rate gradient and lesser stress caused by the lowered quenching temperature.

The C steel quenched in oil from 1080 degrees Cent., Fig. 11 (d), has a structure predominantly martensitic but with troostite throughout the section, somewhat more concentrated near the center. Quenched in water from 800 degrees Cent., Fig. 11 (e), troostite appears only in the center and then mixed with martensite. Accordingly this steel has a slower critical cooling rate than B steel. This difference between the two steels, however, cannot be

attributed to cementite crystallization nuclei, as suggested by Portevin and Garvin 6, for free cementite is present in both steels when quenched from the lower temperature and absent from both when quenched from the higher temperature, Figs. 12, 14 and 15. The somewhat different distributions of troostite in these two steels with the same ratio of troostite to martensite is evidently due to the considerable difference in cooling rate necessary to produce equal ratios.

The above analysis of the experimental results is based on a consideration

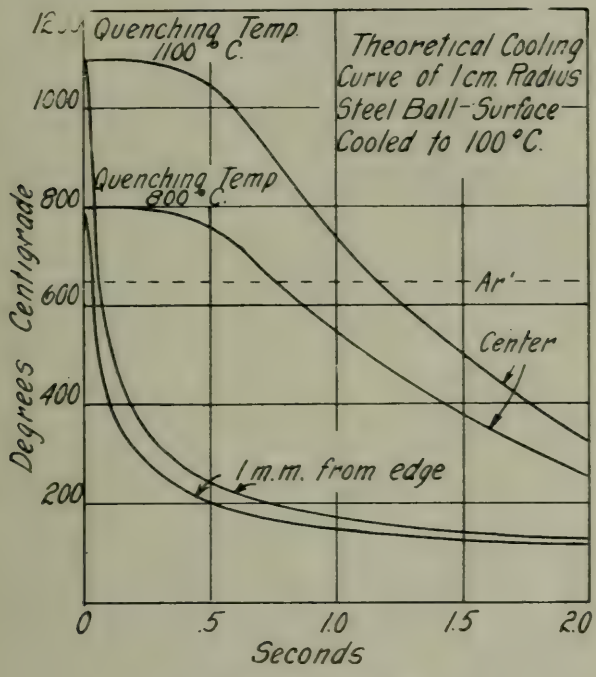


Fig. 18.—Theoretical quenching curves of edge and center of sphere quenched from two different temperatures.

of stress in cooling steel. Briefly, tensional stress favors and compression hinders the formation of troostite at Ar'. The distribution of troostite is, however, dependent also on the rate distribution and subsequent transformation. By choosing conditions which bring one or another of these factors to a maximum they may be plainly revealed. An extensive study of these factors is obviously essential to a solution of the problems of hardening.

The Structure of Martensite

The information presented perhaps justifies some remarks on the constitution of martensite. This, however, requires some definite conception of the allotropic nature of martensite. The recent X-ray crystallographic studies of Jeffries and Archer (16) and of Westgren and Phragmen (18) furnish the long sought answer to this problem. These authors show that martensite has the same space lattice as ferrite and this confirms the so-called alpha-iron theory of hardening for there can be no doubt that the carbon is in solid solution. The first named authors, however, interpret the diffuse lines of

their spectrograms as showing that the grain size of martensite is very small even in steels having a very coarse microstructure. They offer this information as evidence that the hardness of martensite is due to a supposed submicroscopic grain structure. The latter authors confirm the observation that the spectrogram of martensite is such as might be produced by very fine grains, in fact colloidal sized, and submit the additional information that the lattices of both austenite and martensite are enlarged by dissolved carbon.

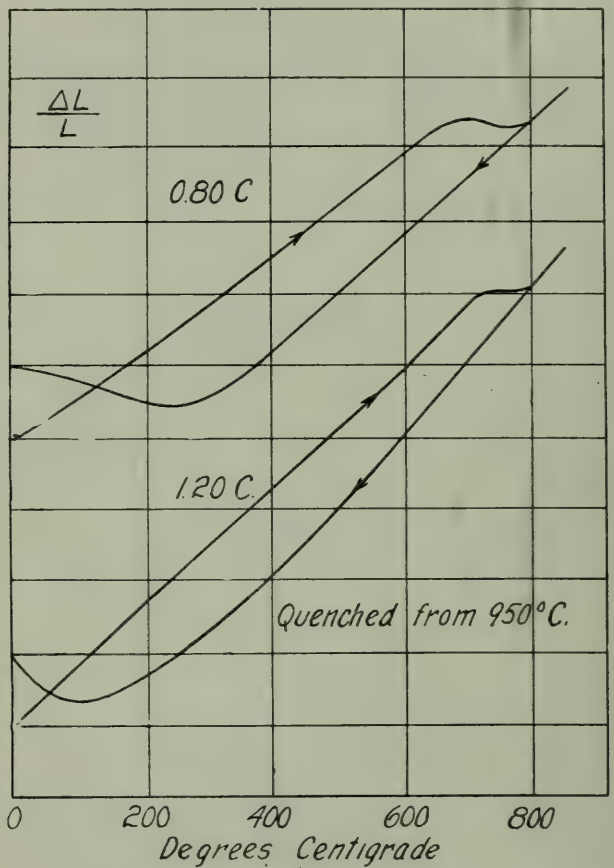


Fig. 19.—Expansion curves of an eutectoid steel and of a hyper-eutectoid steel.

Moreover, the lattice of austenite is not distorted by that element. These observations are, however, a natural consequence of the transformation of austenite to martensite.

The analogy between liquid and solid solutions has been successfully exploited so far as the eutectoid changes go and might well be extended, as by Hanemann (2), to this transformation of solid solution, austenite to martensite which is evidently analogous to that of solidification of solid solutions, for which case a dendritic or heterogeneous structure is normal. The essential difference between the phase change at Ar″ and the freezing of solid solution alloys is that in the former case the homogeneous unit in which

crystallization proceeds is the pre-existing austenite grain and in the latter case the whole melt. The development of segregation units is thereby restricted to a micro scale. Diffusion readily occurs in the austenitic steels while hot and their homogeneity is maintained cold as they undergo no transformation, their spectrum line is consequently sharp, but below the low temperature of Ar″ free diffusion cannot occur so the heterogeneity generated there is not effaced. It is accordingly a normal product of the genesis of martensite.

The units of maximum and minimum concentration in the near-eutectoid steels do not correspond to gamma and alpha-iron solutions as sometimes supposed for there is no roughening of the surface on cooling them to liquid air temperatures and the X-ray spectrum does not show the gamma lattice. Moreover, magnetic analysis at high inductions shows that martensitic eutectoid carbon steel has two definite saturation values (17) which evidently correspond to the units of maximum and minimum concentration. Martensite thus behaves as though composed of two separate constituents differing only in the amount of dissolved carbon. These units, however, are probably not sharply separated, but are continuous from one to another just as are the dendrites and filler of solid solution alloys. Now if carbon opens up the ferrite lattice as Westgren and Phragmen's results indicate, its nonuniform distribution should produce diffuseness of the X-ray spectrum lines no matter what the actual grain size may be. Thus the fact that the X-ray spectrum lines of martensite are diffuse is not conclusive evidence that martensite is exceedingly fine grained.

On the other hand the micrographs of martensite, particularly that of high temperature quenching, show none of the characteristics of severely cold-worked and very fine grained metals. Even the individual needles are fairly large and have noticeable directional properties within a grain. As Sauveur (19) points out in his comprehensive discussion of Jeffries' and Archer's paper, the evidence of submicroscopic grains is very meager and the assumption is hardly necessary to account for the hardness of martensite.

The above developed conception of the constitution of martensite accounts for other familiar characteristics of martensitic steels. The concentration units are naturally larger and better developed the higher the quenching temperature, as observed, for the grain units in which they grow are then larger; likewise they are smaller in areas enclosed by troostite than in purely martensitic areas for the same reason. The grain boundaries are not developed by ordinary etching methods for the concentration differences produce rapid etching over the entire surface completely obliterating the slight contrast between grains and their boundaries. A fair idea of the grain size for a given quenching temperature may, however, be had from such characteristics as the fracture, the contour of quenching cracks, and distribution of excess constituents.

The difference in specific volume between the units of maximum and minimum concentration is probably responsible for the brittleness and characteristic fracture of martensite. The individual grains are accordingly brittle so the fracture is of a different type from that of large-grained, but soft metals.

It is evident from these considerations that quenching temperature is not a simple variable as often supposed. For example, raising the quenching temperature of a hypereutectoid steel increases the rate of cooling and the stress developed; changes the rate distribution and probably the critical cooling rate; increases the amount of dissolved carbon and decreases the amount of free

cementite, lowers the transformation of austenite to martensite and delays its occurrence; increases the grain size and consequently the magnitude of the concentration units. Each of these variables can have an important effect on the final properties of the hardened steel. It is therefore essential in prosecuting investigations of quenching operations to choose experimental conditions which will bring these variables individuality to a maximum so that those having important effects in the problem considered may be recognized and their control effected.

Summary

The results of a micrographic and macrographic study of the effect of high temperature quenching on the structure of three simple high-carbon steels are presented. These data show that a carbon steel can be made austenitic only when sufficient carbon is dissolved, about 1.5 per cent, and maintained in solution, by sufficiently rapid cooling. The critical cooling rate for so producing austenite is, however, very slow in comparison with that of martensitic steels cooled from the same temperature. The surface layers of the austenitic steel were decarburized in all cases at the high temperature obtained to a depth of not more than one millimeter producing two distinct surface layers. The outermost layers contained no free cementite and were martensitic. The intermediate area contained some free cementite, but there were abundant twins and other markings in its austenitic matrix. This condition of the surface has not been recognized in previous investigations of austenitic carbon steel.

The interior austenite produced as noted has the following characteristics:

(1) It contains many thin needles of cementite (plates in three dimensions) forming parallel groups and a cementite network.

(2) The cementite needles separate from the solid solution saturated at 1080 degrees Cent., leaving less than 1.6 per cent carbon dissolved in the austenite.

(3) Twins and slip-bands are developed in the austenite, when the needles are sparse, by cold deformation.

(4) It may be transformed into martensite by immersion in liquid air.

(5) It shows a well-defined structural change on tempering to troostite and the temperature of the end point of this transformation agrees closely with that determined by heating curves.

(6) The change from austenite to troostite is duplex involving the formation of martensite.

(7) The troostite is converted into sorbite on tempering over 500 degrees Cent., and the cementite needles then disintegrate into globules.

Two lower carbon steels 1.04 and 1.16 per cent carbon were martensitic and contained no austenite when quenched from the same temperature as the austenitic carbon steel. Varying the quenching temperature and cooling medium for these steels lead to the following observations:

(a) Their apparent critical cooling rate is faster than that of the austenitic carbon steel, but that of the lower carbon one is slower than that of the higher.

(b) Quenching in oil from the high temperature produced martensite only in the center of the 1.16 per cent carbon steel.

(c) Quenching the 1.04 per cent carbon steel in water from the same temperature produced martensite over the whole section except at the surface where troostite outlined the grains and formed short needles.

(d) A uniform concentric ring of martensite surrounding pure troostite was produced on quenching the 1.16 per cent carbon steel from a normal hardening temperature, only by agitating in water.

An interpretation of these phenomena is made from a consideration of the transformations, the cooling rate distribution, and the stress in steel during cooling. It is shown that troosite of quenching forms at about 650 degrees Cent. in carbon steels with an increase of volume. The interior of the specimen is under compression and the surface in tension when this transformation, Ar′, is reached in quenching. From LeChatelier's principle this favors the formation of martensite in the center and troostite in the outler layers. Thus when the cooling rate producing a mixture of martensite and troostite is slow, the rate will be uniform and the stress negligible so the distribution of troostite is uniform. If a high stress be developed with a uniform rate distribution troostite will form at the edge and martensite at the center. If the stress be low and the rate gradient from center to edge high, martensite will form at the edge and troostite at the center according to the rate distribution. Each of these distributions has been experimentally obtained.

The duplex structure of martensite is shown to be analogous to that of solid solution alloys. This conception requires that the structural units differ only in the amount of dissolved carbon. It is supported by the results of magnetic and X-ray spectroscopic analysis and explains some of the notable characteristics of martensite.

The experiments described here were performed in Prof. Sauveur's laboratory at Harvard University during the term 1920-21, and this paper is the outcome of Prof. Sauveur's suggestions and helpful interest in the work.

Bibliography

Metallography of Austenitic Carbon Steels

(1) Osmond and Stead—"The Microscopic Analysis of Metals." Chas. Griffin & Co., 1913.
(2) Hanemann—"Einfuhrung die Metallographie und Warmebehandlung." Gebruder Borntraeger—Berlin, 1915.
(3) Benedicks—Journal of the Iron and Steel Institute. 77:153 (1909).
(4) Maurer—Revue de Metallurgie. 5:711 (1908).
(5) Scott & Movius—Bureau of Standards Scientific Papers No. 396.

Transformations in Cooling Steel

(6) Portevin and Garvin—Journal of the Iron and Steel Institute. 99:469 (1919).
(7) Chevenard—Revue de Metallurgie. 14:601 (1917).
(8) Chevenard—Compt. Rend. 165:59 (1917).
(9) Honda—Journal of the Iron and Steel Institute. 100:417 (1919).
(10) Scott—Bureau of Standards Scientific Papers. No. 335.
(11) Scott—Bureau of Standards Scientific Papers. No. 376.

Temperature Distribution and Stress in Cooling Steel

(12) Tafel—Stahl und Eisen. 41:132 (1921).
(13) Wille—Proceedings of the American Society for Testing Materials. 152:27 (1915).
(14) McCance—Journal of the Iron and Steel Institute. 89:192 (1914).
(15) Heindlhofer—Phys. Rev. 20:221 (1922).

Constitution of Martensite

(16) Jeffries and Archer—Chemical and Metallurgical Engineering. 24:1057 (1921).
(17) Nusbaum, Cheney & Scott—Bureau of Standards Scientific Papers. No. 404.
(18) Westgren & Phragmem—Journal of the Iron and Steel Institute. Sept., 1922.
(19) Sauveur—Chemical and Metallurgical Engineering. 25:509. (1921).

EXPERIMENTS ON THE RAPID GRAPHITIZATION OF WHITE CAST IRON AND A THEORY FOR THE MECHANISM OF GRAPHITIZATION

By Anson Hayes, W. J. Diederichs and W. M. Dunlap

Abstract

The authors of this paper have described the results of experiments conducted in graphitizing white cast iron. Various heating and cooling treatments were applied to specimens of white iron for varying periods of time ranging from 1 to 60 hours. Photomicrographs were made of these, several of which are included in this paper. These photomicrographs show typical structures obtained in the investigation. The physical properties of the specimens which were tested are likewise included in this report.

The authors have formulated a theory for the mechanism of the graphitizing action which includes a discussion of the work that has been done in the past by other investigators.

IN 1916 one of the writers was engaged in instructing students in the properties of the various cast irons in the materials testing laboratory at Cornell university. The supply of malleable iron test pieces was exhausted but there was still a stock of white iron test samples on hand. It was decided to attempt to malleablize some of the latter rapidly, making use of high temperatures, and to demonstrate the properties resulting, at the same time, of course explaining the treatment to which the material had been subjected. There were two specimens which showed a surprisingly high tensile strength, the value being in the neighborhood of 60,000 pounds per square inch, but the elongation was practically nil.

Noting this high strength, numerous experiments were run which resulted in a product which consistently showed strengths ranging from 70,000 to 85,000 pounds per square inch, with elongations of about 1 per cent. Most of these products could be machined rather readily by the use of ordinary lathe tools and a finished machined piece had a surface which was rather difficult to distinguish from a similarly finished piece of steel.

Discussion of these results by the writers led to the conclusion that the imparting of appreciable elongation to this high strength material was possible from theoretical considerations. Furthermore, the possible commercial importance of such a product led the writers to institute a research in an attempt to develop it.

We have found it possible, at least in the laboratory, to repeatedly impart a considerable elongation to the resulting product by two methods while retaining the high strengths. In addition we have found it possible to produce by two methods a malleable iron which duplicates closely malleable iron annealed by the commercial process from the same heat. The total time required to produce malleable iron by these laboratory methods was about 45 hours and there is no doubt that the time required to accomplish

---

A paper presented by Dr. Anson Hayes before the Detroit Convention of the Society, October 2-7, 1922. Of the authors, Dr. Anson Hayes is associate professor of physical chemistry and metallography. W. J. Diederichs is associate professor of mechanical engineering and W. M. Dunlap is a graduate student of metallography, all of Iowa State College, Ames, Iowa.

the same end can be materially reduced. It seems very possible that these laboratory processes can be made of commercial importance.

It is the object of this paper to describe these experiments, to discuss the products resulting from these processes and to discuss the theory underlying the mechanism of graphitization.

Material and Apparatus

The material used consisted of two different melts and was cast in the form of one-half inch standard tensile test bars. The bars were used as cast. The analysis of the white iron from the two heats follows:

Constituent	Melt No. 1 per cent.	Melt No. 2 per cent.
Silicon	0.90	0.08
Sulphur	0.041	0.037
Phosphorus	0.181	0.178
Manganese	0.22	0.24
Total Carbon	2.24	2.39

Fig. 1 shows a photomicrograph typical of this white cast iron. This is a typically normal structure and needs no further comment. Fig. 2 shows a photomicrograph of a malleable test bar made from melt number 1 and annealed along with commercial run of work by the regular commercial method.

The average tensile test results of both the white iron and malleable iron supplied us follows:

	Melt No. 1		Melt No. 2	
	Tensile strength lbs. per sq. inch	Elongation per cent in 2 inches	Tensile strength lbs. per sq. inch	Elongation per cent in 2 inches
White iron	51,000	0	55,000	0
Malleable iron	54,000	22	57,300	19

It might be remarked in passing that these results show a material of exceptionally high quality. The heat treatment was carried out in two electric furnaces. One was a muffle furnace having a 7 x 12 inch hearth, the other was a "Hump" furnace with 10-inch diameter heating chamber. The former was controlled by a sectionally wound transformer and the latter by a rheostat in series with the furnace windings, supplemented by a set of parallel resistances making extremely accurate control possible.

The temperature measurements were made with a chromel-alumel couple, or a platinum-platinum rhodium couple both calibrated against a Bureau of Standards rare metal couple. Temperature measurements were made on a potentiometer indicator which was used for all runs except in the case where a very slow cooling was desired. In this case temperature measurements were recorded on a recording instrument. These combinations of couples and indicators were also calibrated against a Bureau of Standards reference electromotive force. All tensile tests were conducted in a 50,000 pound hand operated universal machine which was calibrated before using.

Experiments, Results and Discussion

The first series of experiments which will be indicated as experiment A, was conducted to determine the rate of graphitization at a temperature of 1000 degrees Cent. The ideal method would have been to introduce the test specimens into the furnace while at temperature so that length of time

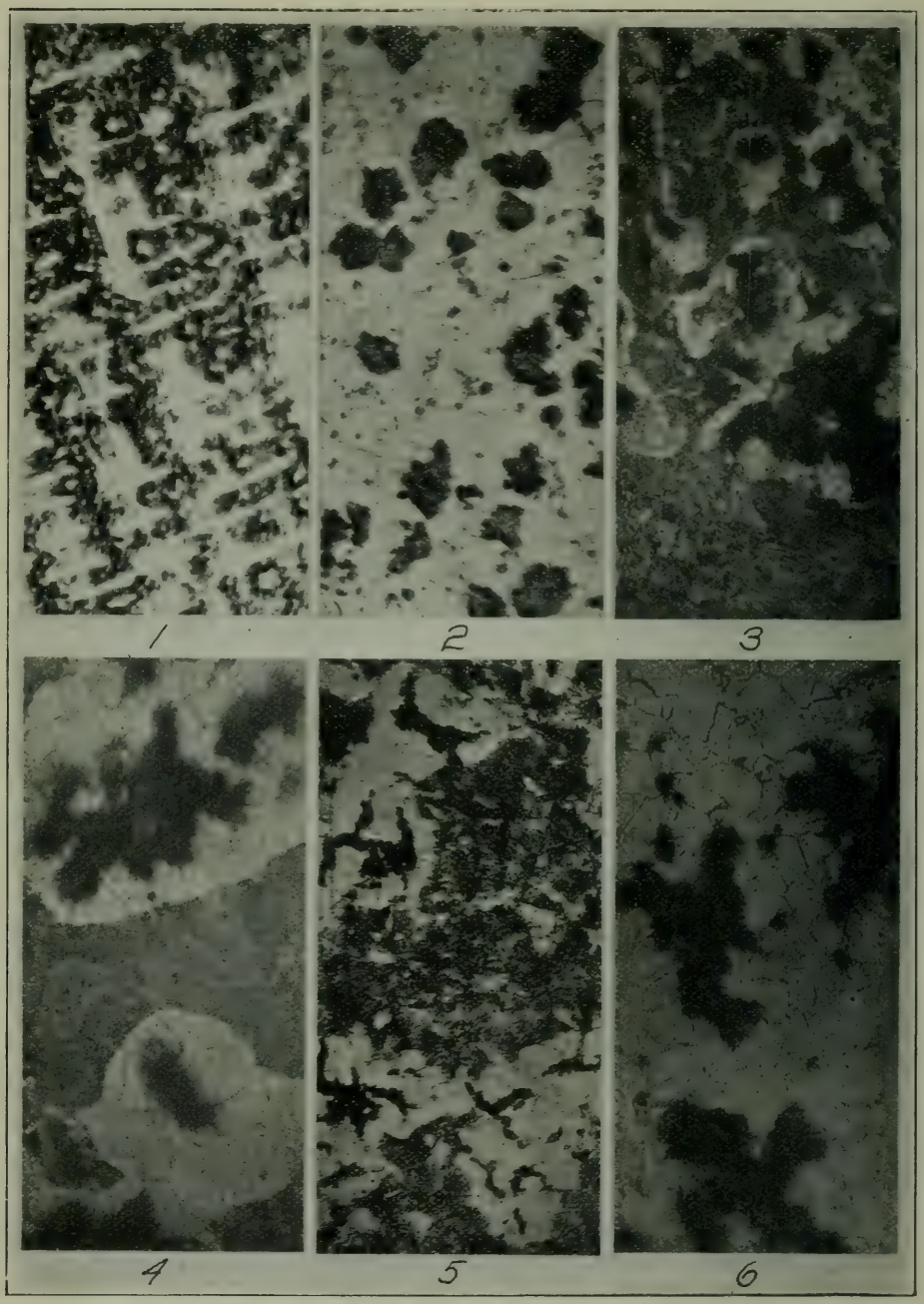


Fig. 1—Photomicrograph showing typical structure of white cast iron. × 150. Fig. 2—Photomicrograph of a malleable test bar made from melt No. 1 and annealed along with a commercial run of work. × 75. Fig. 3—Photomicrograph of specimen held for 4 hours at 1000 degrees Cent. and furnace-cooled. × 100. Fig. 4—Specimen held for 60 hours at 1000 degrees Cent. and furnace-cooled. × 100. Fig. 5—Treatment B resulted in incomplete graphitization. Considerable ferrite deposition took place around the carbon spots. × 100. Fig. 6—Treatment C resulted in complete graphitization. × 100.

under graphitizing conditions could have been accurately noted. On account of the small size of furnace and the large number of pieces required to complete the series, this was found impossible, since the furnace would rapidly drop in temperature on introducing the charge. The pieces were therefore charged into the cold furnace and the whole brought to temperature as rapidly as possible. It required about two hours to come to a temperature of 1000 degrees Cent., after passing the critical temperature. Three pieces were removed at a time at intervals after attaining temperature and cooled in sand, as noted in Table I. The table also includes the tension test results based upon an average of three pieces.

It will be noted that two furnaces were used in completing this series of runs. Any slight variation in the time necessary to come to heat will not

Table I.

Tensile Strength and Ductility of Specimens Treated Under Experiment A.

Time of Temperature of 1000 degrees Cent.	Strength lbs. per sq. inch	Elongation per cent in two inches	Remarks	
20 mins.	84,100	0	Muffle	furnace
30 mins.	87,500	0	"	"
45 mins.	90,600	0	"	"
1 hour	85,600	0	"	"
2 hours	83,600	0	"	"
3 hours	89,000	0	"	"
4 hours	83,200	1.0	"	"
6 hours	81,600	0	Hump	Furnace
12 hours	83,900	0	"	"
18 hours	86,000	0	"	"
24 hours	83,800	0	"	"
30 hours	83,700	0	"	"
36 hours	83,400	0	"	"
42 hours	82,800	0	"	"
48 hours	84,400	½	"	"
51½ hours	83,100	½	"	"
54 hours	83,400	0	"	"
60 hours	81,800	¼	"	"

appreciably effect the results shown, since no comparisons are made until after five hours have elapsed. At the end of the 4 hour run in the muffle furnace, the specimens were allowed to cool normally with the furnace and similarly, after the 60 hour run in the Hump furnace the specimens were permitted to cool normally with the furnace. The average properties of these bars are shown in the following:

Time at temperature of 1000 degrees Cent.	Strength lbs. per sq. in.	Elongation per cent 2 inches	Remarks
4 hours	74,200	1	Cooled in and with muffle furnace
60 hours	76,900	4.5	Cooled in and with Hump furnace

Microscopic study of all of the specimens whose physical properties are listed in Table I brought out the following points of interest:

1. Graphitization was advanced to a remarkable extent within 20 minutes after coming to a heat of 1000 degrees Cent., and temper carbon spots were evenly distributed throughout the section. The temper carbon deposit increased slightly as the heating period was increased to 3 or 4 hours and thereafter increased time of heating had very little, if any, effect upon the carbon deposition.

2. Massive cementite was present to an appreciable extent in the

specimen heated for only 20 minutes. As the time of heating was increased the amount of massive cementite decreased until after a heating period of 3 or 4 hours practically all traces of massive cementite had disappeared.

3. The ground mass in all of these specimens was pearlite and sorbite and in no case was there evidence of any free ferrite.

The fact that all of these specimens have this very similar structure accounts for the uniformity of tension test results shown in Table I.

Figs. 3 and 4 show the photomicrographs corresponding to the specimens whose tensile properties are listed above. It is noticeable that there is a slight deposition of free ferrite around the temper carbon in the specimen heated for 4 hours, and that there is a marked deposition of free ferrite in the specimen heated for 60 hours. This increase in free ferrite accompanied by increased carbon deposition accounts for the increased elongation of the latter specimen.

It is to be noted that the muffle furnace, due to poorer heat insulation, cooled approximately twice as rapidly as the other furnace through the critical range. The writers believe that this difference in ferrite deposition is mainly due to this variation in cooling rate rather than to the variation in time of heating at 1000 degrees Cent. This belief is held because the specimens heated for 4 hours and 60 hours at 1000 degrees Cent. and both cooled in sand showed the same structure except for the disappearance of a small amount of intergranular material in the 60 hour specimen. This point will be discussed in greater detail later in this paper.

Consideration of these results, led us to conduct the following experiments:

Experiment B. Test bars were heated at 1000 degrees Cent. for 1 hour, were cooled to 850 degrees Cent. with the furnace, were held at 850 degrees Cent. for 6 hours and then were cooled in the furnace to below the critical temperature.

Experiment C. Another bar was treated similarly except that it was finally cooled from 850 degrees Cent. through the critical range at a rate of about 4 degrees Cent. per hour.

It seemed that 1 hour at 1000 degrees Cent. was ample to start the reaction and absorb most of the massive cementite, and the temperature was dropped to 850 degrees Cent. to prevent undue grain growth. A time of 6 hours at 850 degrees Cent. was arbitrarily chosen to allow an approach to equilibrium at that temperature.

Since the number of bars were relatively few in these experiments, they were inserted in a furnace already at heat and it was possible to bring them to heat in about 20 minutes. The tensile properties of these bars follow:

Treatment	Tensile Strength lbs. per sq. in.	Elongation per cent in 2 inches
B	62,000	5
B	62,600	5
C	49,200	16.5

Fig. 5 shows that treatment B resulted in incomplete graphitization but that considerable ferrite deposition had taken place around the temper carbon spots. The ground mass was pearlite. Fig. 6 shows that treatment C resulted in complete graphitization and the product is malleable iron of good

quality as shown by the physical test. The temper carbon is not of ideal form. This point will also be taken up in greater detail later.

Experiment D. Bars were alternately heated and cooled in the furnace between the temperatures of 850 and 650 degrees Cent. for the number of times indicated.

Experiment E. Bars were alternately heated and cooled just as in Experiment D, except that the final cooling from 850 degrees Cent. was at the rate of 4 degrees Cent. per hour.

The tensile properties of these bars follow:

Number of times heated to 850 degrees Cent.	Treatment D		Treatment E	
	Tensile Strength lbs. per sq. in.	Elongation	Tensile Strength lbs. per sq. in.	Elongation
3	77,500	2	62,400	1.5
5	85,500	1.5	44,400	10
7	52,700	4	47,000	15
9	57,700	5	46,000	17.5
13	70,500	5	45,000	13.5
15	66,000	4	47,500	14.5
17	71,500	5.5	47,500	14
19	59,400	5	44,000	14

Experiment F. In conjunction with Experiment D, Experiment F was run in a similar manner except that the bars were sand cooled instead of furnace cooled, the final cool being with the furnace as before.

Experiment G. In conjunction with Experiment E, Experiment G was run in a similar manner except that the specimens were cooled in the sand. The final cool was at the rate of 4 degrees Cent. per hour as in Experiment E.

The tensile properties of these bars follow. Unfortunately the results of repetitions of heating less than 13 times have been lost.

Number of times heated to 850 degrees Cent.	Treatment F		Treatment G	
	Tensile Strength lbs. per sq. in.	Elongation	Tensile Strength lbs. per sq. in.	Elongation
13	74,600	3.0	50,000	15.5
15	71,250	2.5	51,600	14.0
17	84,700	5.5	49,100	16.0
19	82,900	6.0	47,000	17.5

Figs. 7 and 8 are photomicrographs showing typical structures obtained by the use of treatment D. It is to be noted how rapidly the massive cementite is disappearing and temper carbon is being produced due to only 3 repetitions of heating and cooling as shown by Fig. 7. Deposition of free ferrite is also evident to a slight extent.

Fig. 8 shows that further repetitions of heating and cooling produce only slightly further changes in structure, these being mainly a further elimination of free intergranular cementite. By this method we never succeeded in our experiments, in completely eliminating the last traces of massive cementite. Fig. 8 shows a structure whose ground mass is almost entirely pearlitic. It is interesting to note that previous calculation had led us to believe that if a ground mass of pearlite could be obtained we might expect a strength of 90,000 to 100,000 pounds per square inch and an elongation of 6 to 7 per cent in this material. These properties are of that order of magnitude.

Fig. 9 is a photomicrograph showing the structure obtained by treatment F. It is not greatly different from the structure of Fig. 8, except

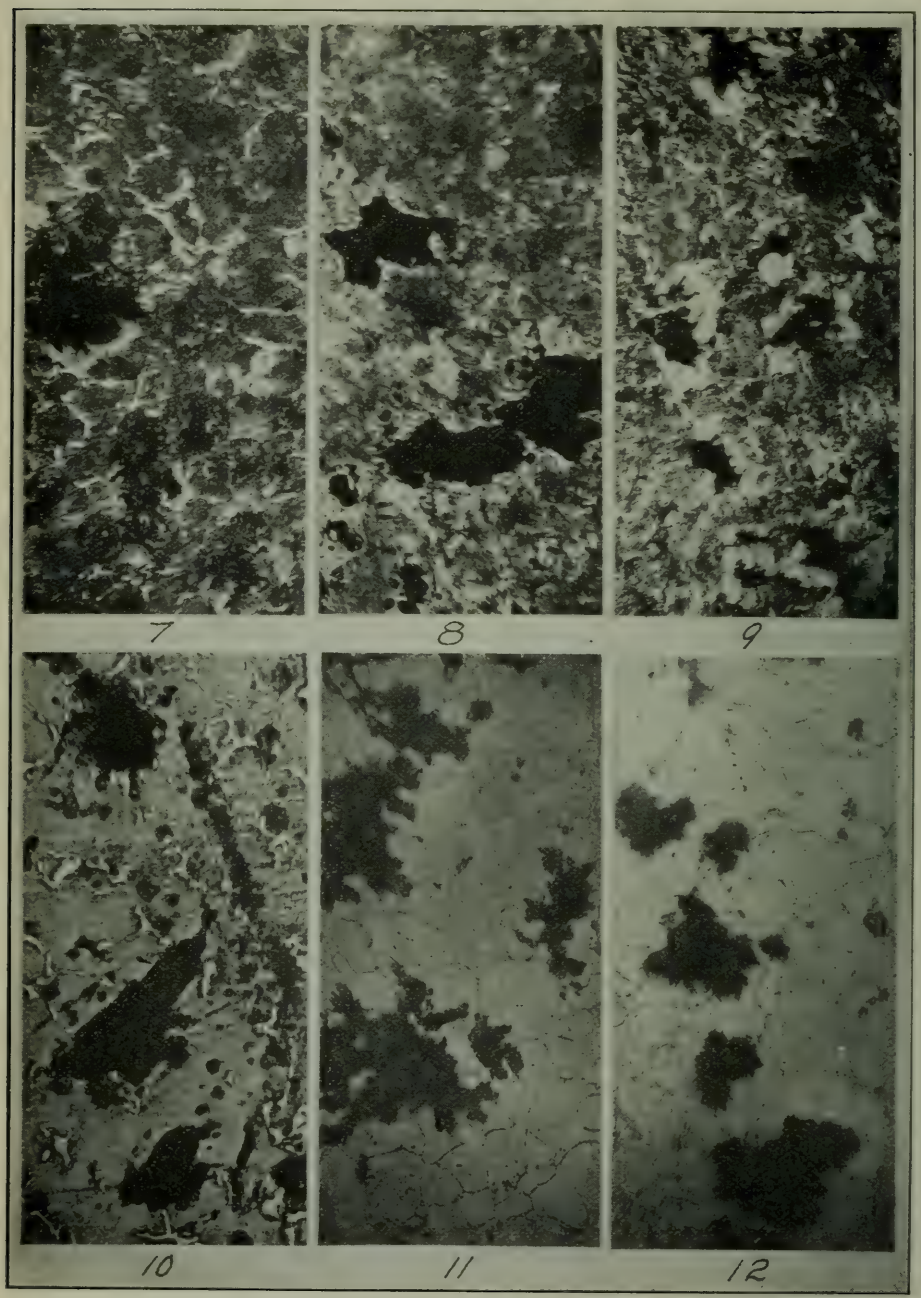


Fig. 7—Photomicrograph showing typical structures obtained by the use of treatment D, three repetitions. × 100. Fig. 8—Same treatment as Fig. 7, 17 repetitions. Ground mass almost entirely pearlitic. × 100. Fig. 9—Photomicrograph showing structure obtained by treatment F, 17 repetitions. × 100. Fig. 10—Photomicrograph showing structure obtained by treatment E, three repetitions. × 100. Fig. 11—Same as Fig. 10 with 17 repetitions. × 100. Fig. 12—Photomicrograph of structure resulting from treatment G, 17 repetitions. × 100.

that there is a somewhat greater deposition of free ferrite due to the final cooling having been slighly slower in this particular case, and a finer grain due to the fact that it was above the critical range for a shorter time on each repetition of heat. The finer grain probably accounts in the main, for this increased tensile strength.

The structures in Figs. 10 and 11 are typical of those obtained by treatment E. It is evident that when the repetitions are sufficiently numerous a malleable iron of excellent physical properties results. By comparing these figures with Figs. 7 and 8, it is noteworthy that a slow cooling through the critical range at the rate of 4 degrees Cent. per hour has no appreciable effect on the massive cementite. This indicates that if time is to be considered, it is advisable to absorb all massive cementite at temperatures well above the critical. Fig. 12 shows the structure resulting from treatment G and is very similar to that shown in Fig. 11 and needs no further comment.

Attention should be called to the fact that temper carbon deposited by these rapid methods of repeated heating to, and cooling from, 850 degrees Cent. is of good form. It is also to be noted that only in treatments B and C presented thus far in this paper has the form of temper carbon deposited been at all bad. In this connection it becomes interesting to present Fig. 13, which illustrates what may be done in producing variations in carbon form, although the maximum temperature used in producing this was also 1000 degrees Cent. This specimen was introduced singly into a furnace held at 1000 degrees Cent. and was brought to heat in about 12 to 15 minutes. Other specimens as already noted were brought to heat more slowly. It is possible that this furnishes a clue to the control of temper carbon form even though high temperatures are used. It is possible that the form of temper carbon first deposited has a marked effect upon the form of that deposited later. This point is being made the subject of further investigation in this laboratory.

Graphitization Theories

The writers have formulated a theory for the mechanism of the graphitizing action. To our knowledge no comprehensive theory of the mechanism of the complete graphitization of white cast iron has been presented. It has been suggested by a number of investigators that the solubility of cementite (Fe_3C) in gamma iron is greater than that of carbon (C). In this opinion the writers concur and it readily suggests a mechanism of breakdown at temperatures above the critical range. What happens on cooling slowly through the critical range is a point in dispute, for which the authors believe no comprehensive theory has been advanced. For instance H. A. Schwartz[1] indicates that the solubility of carbon in iron decreases continuously with decrease of temperature until it reaches zero at the lower critical temperature, A_1. This necessitates that the eutectoid shifts practically to zero carbon concentration and that no ferrite separates out until A_1 is reached. This does not agree at all with the action of low carbon steel in traversing the same range. The failure of ferrite to separate from the solid solution at the point where the carbon solubility curve crosses the A_{2-3} line of the steel range is inconsistent with the known action of low carbon steels.

Archer[2] holds that the carbon solubility decreases continuously until it reaches approximately 0.7 per cent at A_1 and that the final decomposition

1. The *Iron Trade Review*, Feb. 3, 1921, page 353.
2. *Transactions* of the American Foundrymen's association, Vol. XXVII, 1918, page 351.

of cementite occurs below A_1. Nothing is said as to what happens between the temperatures corresponding to the point of intersection of the carbon solubility curve with A_{2-3} and the temperature of A_1.

Merica and Gurevich[3] make the statement, "The fact that only 0.2 per cent of combined carbon was found in some specimens after annealing at high temperatures and cooling slowly in the furnace would indicate either that the graphite eutectoid lies at much lower values of carbon content than has been previously supposed, that there is at those rates of

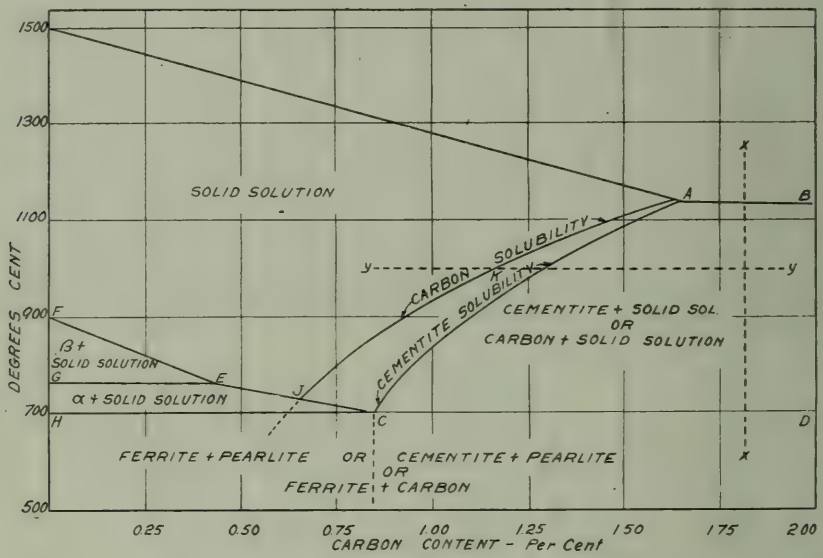


Fig. 16—Iron-Carbon Constitutional Diagram

cooling a direct precipitation of graphite eutectoid, or that there is a formation of graphite from pearlite at temperatures below that of its formation."

In both the latter references the possibility of a breakdown of pearlite to temper carbon and ferrite at temperatures below A_1 is mentioned. Such action is also inconsistent with the behavior of pearlite in steels and with the behavior of massive cementite at this temperature as well as at higher temperatures.

Origin of the Bull's-Eye Structure

In examining our furnace-cooled specimens it was noted that in a considerable number of instances there was actual contact between pearlite and the temper carbon spot; this contact being made through an opening in the ferrite ring of the "bull's-eye" structure. At temperatures above A_1 this pearlite must have been solid solution of eutectoid composition. This suggested directly that the growth of the temper carbon spot was effected by diffusion of carbon through the solid solution, and not by a diffusion of carbon through the ferrite ring. The writers can not conceive of any other method of growth, if it is granted that ferrite cannot take carbon in solution and therefore cannot act as a diffusion medium. Very often temper carbon spots completely surrounded by a ferrite ring are noted. The view

3. *Bulletin* of the American Institute of Mining and Metallurgical Engineers, July, 1919, page 1063.

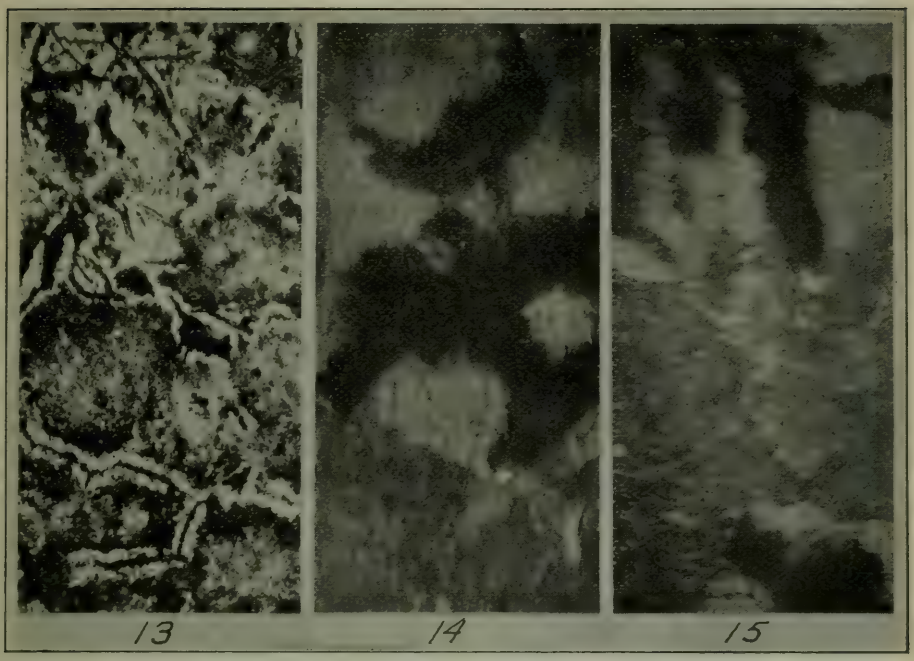


Fig. 13—Photomicrograph illustrating what may be done in producing variations in carbon form. This specimen was introduced singly into a furnace held at 1000 degrees Cent. and was brought to heat in 12 to 15 minutes. × 100. Fig. 14—Photomicrograph showing contact between the pearlite and the temper carbon spot. × 150. Fig. 15—Similar to Fig. 14. × 400.

is from one plane only, and it must be remembered that there are numerous other planes which might have been chosen, any one of which might have shown the contact of which we speak. The authors believe that the complete enclosure of the temper carbon spot by a ferrite shell would prohibit further growth.

This idea of growth, namely that the growth takes place from solid solution areas, is in conformity with that given by Phillips and Davenport[4] for temperatures above the critical for which they show photographic evidence. Further evidence is submitted in Figs. 14 and 15. These photographs show contact between the pearlite (which at higher temperatures was solid solution) and the temper carbon spot. In partially malleablized material in which the temper carbon deposits were elongated, it was frequently noted that such contact appeared at the extremity of the elongation. The contact is often masked in a microscopic view of a section, because carbon being softer is, during polishing, swept out to a lower level than the surrounding metal.

Theory for Complete Graphitization

If it is true that cementite or carbon going into solution in gamma iron results in identical solid solutions when equilibrium is attained, then it must follow that the simultaneous precipitation of temper carbon and Beta iron, or temper carbon and ferrite, will take place at an equilibrium temperature corresponding to that of the intersection of the carbon solu-

4. *Transactions* of the American Institute of Mining and Metallurgical Engineers, Special Paper No. 1178, January, 1922.

bility curve with the A_3 or A_{2-3} lines. In order to make these points clear these processes will be briefly traced out on the constitutional diagram Fig. 16.

Assume that we heat a white cast iron of composition X-X to 1000 degrees Cent. On passing the critical temperature the ground mass of the iron becomes solid solution and the absorption of massive cementite begins. This absorption of cementite continues as the temperature rises, due to the fact that its solubility increases with temperature. Upon holding at 1000 degrees Cent. massive cementite continues to be absorbed and at the same time carbon is being deposited since the solubility of cementite is greater than that of carbon. This process will continue until equilibrium is reached

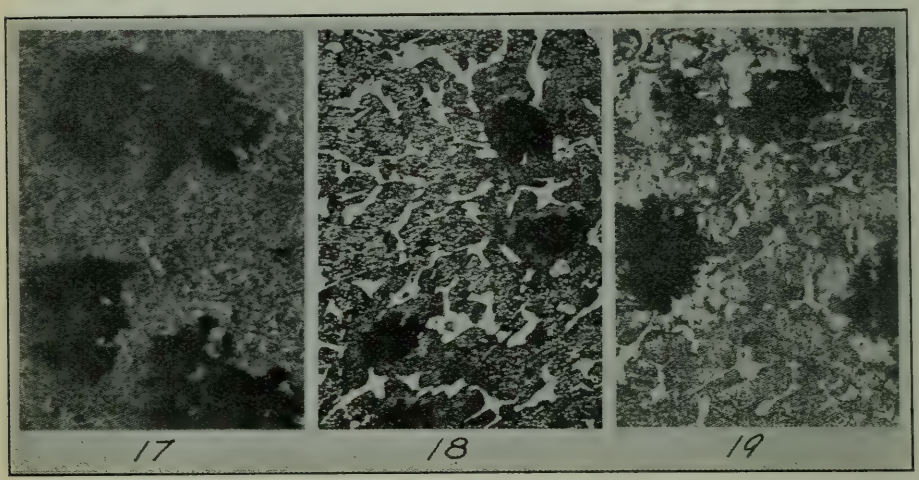


Fig. 17—Equilibrium at 920 degrees Cent. after 70 hours. Black represents temper carbon; gray and white, martensitic mixed crystals. × 100. (After Schwartz.) Fig. 18—Photomicrograph of white cast iron quenched after being held at 800 degrees Cent. for 18 hours. × 100. Fig. 19—Same as Fig. 18 but held for 48 hours before quenching. × 100. (After Phillips and Davenport.)

between carbon and solid solution at this temperature as indicated by the point K. This process is comparatively rapid due to the high temperature. The same action would occur if other temperatures had been chosen, the only variation being a change in speed due to change in temperature.

Now, if the specimen is slowly cooled the composition of the solid solution will traverse the line *KJ* which means the depositing of excess carbon as the temperature is lowered until the carbon concentration reaches the value corresponding to *J*. At this point simultaneous precipitation of ferrite and temper carbon should begin. At this temperature it should only be necessary to slowly extract sufficient heat in order to effect complete graphitization. It is conceivable that sufficiently slow supercooling below the temperature of *J* would result in extending the line *AJ* down to the temperature of A_1 or below, and the action of graphitization continue as outlined. A number of investigators have reported graphitization continuing at these low temperatures. The potential producing graphitization would be increased by such undercooling and also continuous deposition of temper carbon would be favored by extensive and intimate contact with temper carbon already present. The only condition necessary to the actions outlined is that

at some time during the process the temperature of the metal must have been above the temperature corresponding to *J*.

The effect of rates of cooling more rapid than those necessary to bring about the action mentioned in the preceding paragraph would be the precipitation of ferrite in excess of that corresponding to points on an extension of the line *AJ* and would result in the composition of the solid solution shifting along the line *JC*, or nearly so, until the point *C* had been reached, at which time precipitation of pearlite would occur. It is common experience that too rapid cooling from these temperature regions results in some pearlite being obtained. During this shift of composition free ferrite is necessarily deposited. This might result in the complete surrounding of a temper carbon spot by a ferrite shell. In this case, just as in our previous discussion of the genesis of temper carbon spots, it is evident that the carbon spot was always in contact with solid solution during its growth.

The behavior of the solid solution as outlined, is in conformity to the known action of steels. It is a well known fact that graphitization of distinctly hypo-eutectoid steels does not occur under ordinary conditions for heat treating steels. This is due to the facts that no temper carbon contact is possible above temperature *J* and therefore during cooling there is no intimate temper carbon contact to favor the deposition of this form of carbon, and on cooling to lower temperatures when A_2-$_3$ is reached ferrite separates out of the solid solution until eutectoid composition is reached at which time pearlite is formed. It is also a well known fact that graphitization in a hyper-eutectoid steel can occur, particularly if the carbon is above 1.2 per cent. It is very probable that in this case when the steel is held at high temperatures for the long times known to be necessary to graphitize such steels, the excess cementite goes into solution causing a deposition of temper carbon and the action is entirely similar to that of white cast iron subjected to similar treatment.

The exact location of the line *AJ* is not known. It is generally considered that silicon causes the eutectoid composition (point *C*) to shift to the left. Since silicon displaces carbon in solid solution, it is probable that the point *J* also shifts to the left. In other words silicon may cause a decrease in the slope of both the lines *AC* and *AJ*. The fact that high silicon greatly increases the rate of graphitization seems to imply that the presence of this element increases the angle between these two lines. Such an increase in angle would bring two hastening factors into play; first, a greater difference in solubility of cementite and carbon at any temperature and, second, an increase in the temperature at which *AJ* meets A_2-$_3$. It is possible that the point *J* lies on A_3 in which case beta iron and carbon would first precipitate, the beta iron later converting to alpha iron when the temperature had been sufficiently reduced.

According to this theory neither beta iron nor ferrite could form during the annealing of white cast iron until the temperature of annealing had fallen to a temperature corresponding to the intersection of the line *AJ* and the line A_3 or A_2-$_3$. In this connection the writers would call attention to Fig. 17, taken from the paper by Schwartz already cited. This specimen was heated at 1700 degrees Fahr. (920 degrees Cent.) for 70 hours until it was thought that equilibrium conditions at this temperature had been attained. The specimen was then presumably quenched since martensitic structure is shown. Also we present Figs. 18 and 19 which are reproductions of figures 33 and 35 of the paper by Phillips and Davenport. Fig. 18 represents a specimen

of white cast iron quenched after being held at 800 degrees Cent. for 18 hours. Fig. 19 represents a like specimen quenched after 48 hours.

It is to be noted from Fig. 17 that no ferrite forms even when equilibrium is attained at 920 degrees Cent. Fig. 19 gives us a point of particular interest in that ferrite has started to appear at a temperature of 800 degrees Cent. in 48 hours. It is interpreted from this fact that the carbon solubility curve intersected the line A_3 at about 800 degrees Cent. The failure of the ferrite to appear in the specimen quenched after 18 hours is entirely due to insufficient time being given. Another photomicrograph in Phillips and Davenport's paper shows that increasing the time at 800 degrees Cent. increases the deposition of free ferrite. The slowness of the reactions in this region are strikingly indicated.

That the time for attaining equilibrium at 1000 degrees Cent. is also great is indicated by a careful microscopic study of the specimens used in our experiment A. It has already been noted that massive cementite had disappeared in from 3 to 4 hours at 1000 degrees Cent., showing that this constituent was completely in solution in this time. In specimens held at 1000 degrees Cent. for times up to 4 hours grain boundary cementite appeared. With longer periods of time beyond 4 hours this grain boundary cementite gradually disappeared until it was practically nil at 36 hours. Periods longer than 36 hours at 1000 degrees Cent. did not cause any ferrite grain boundary material to appear. This shows that the solubility value of carbon in gamma iron for this specimen was of approximately eutectoid composition, and that the equilibrium condition for carbon solubility in gamma

The explanation of the rapid rates of graphitization obtained by the alternate heating and cooling methods lies in the large angle that exists between the lines *AC* and *AJ*. On heating, the concentration of carbon in the solid solution approaches that of cementite at the temperature chosen. At this time the solubility of carbon in iron is exceeded by a certain amount. On cooling this solid solution, the excess concentration of carbon in solution over and above that corresponding to the solubility of carbon increases. During this cooling there also may have occurred an excess of carbon concentration necessary to satisfy the cementite solubility. In any case the tendency to deposit temper carbon as such is increased. This explanation is essentially the idea presented as a possibility by Phillips and Davenport at the end of their recent paper which came to our hands after our experimental work was completed. It is pleasing to us to note that other investigators were reasoning along the same lines.

Summary

In summarizing the results of this investigation it was found that

1. Cast irons having a strength of 80,000 to 85,000 pounds per square inch tensile strength with no elongation have been produced.

2. Cast irons having a strength of 60,000 to 80,000 pounds per square inch tensile strength with 5 per cent elongation have been produced.

3. Malleable cast irons having good physical properties have been produced in a 45 hour annealing time, and can be produced in even shorter time.

4. A theory for the mechanism of graphitization is presented.

In conclusion the authors wish to make the following acknowledgments: To the Iowa Malleable Iron Company of Fairfield, Iowa, who furnished us

the test bars and were ready to co-operate in every way possible. To Messrs. A. H. Swanson, R. J. Wolf and A. M. Reeder who gave considerable assistance in experimental work, and especially to W. M. Dunlap who gave such valuable assistance in all experimental work during the entire course of the investigation. His name has been properly included as one of the authors.

Discussion of Dr. Hayes' Paper

Chairman Archer: Are there any questions or any discussion on this paper?

Mr. Harder: There is one question that I think doesn't relate directly to the address, but relates to grain growth in ferrite. I have been somewhat interested in the possibility of grain growth in pure iron. For example, at a temperature of say 600 degrees Cent. I wondered if you have observed whether or not, with a given grain structure before heat treating, it would show a definite grain growth at say 600 degrees Cent.

Dr. Hayes: We have not established that point. That is an explanation of the series of points corresponding to the temperature of 600 degrees Cent. shown on this same diagram. There has been brought to our attention by some reliable firms the fact that there is a distinct change of fracture of malleableized cast iron on reheating to 600 degrees Cent. but we have not been able to detect any difference between the structure below 600 degrees Cent. or above. That has been made the subject of an extensive investigation by a number of other people. We have not tried it out. In fact, I expect it would be very difficult to try that point out with a great deal of satisfaction in partially remalleableized material.

Chairman Archer: This paper consists of two chief parts: one, the presentation of the actual test results, and the other the theoretical discussion. If you think back to the first part, there may be some questions on that. I have done some work on this problem myself, of rapid annealing, and considered all the possible ways I knew of to get good malleable in a short time, and finally I came to the conclusion that it could be done in somewhere around fifty hours. I heard this morning that there have been some commercial furnaces built which are accomplishing complete annealing, with no combined carbon remaining, in 45 to 60 hours. The malleable of very high strength, that is, above 60,000 pounds per square inch, always contains combined carbon, and apparently there is not much demand for that kind of material. The malleable people have considered the production of semi-malleableized iron as you have, and appear to believe that the product wanted is a completely annealed iron, with no combined carbon, and ductility as high as possible. I believe they are right in that judgment. I believe ductility is the quality that is responsible for the use of malleable castings.

With regard to this rapid fluctuation of temperature, that is a commercial impossibility, because malleable must be annealed cheaply, the actual cost is under one cent per pound, I think, and sometimes it is considerably under. That requires the heating of large batches

of material at one time, and large batches of material cannot have their temperature changed, either up or down, in a short space of time. Therefore, the heating and cooling must be slow.

In regard to the employment of high temperature anneals, such as 1000 degrees Cent. one important consideration to be kept in mind is the distortion of the castings, due to their softness at the high temperature. They have to be very carefully supported if you are going to heat them to 1000 degrees Cent. without changing the shape.

Dr. Hayes: I would like to ask some practical men a question as to what would be the possibility of a partially malleableized product, showing 90,000 to 100,000 pounds tensile strength and 6 per cent elongation as displacing some of the uses of steel, at the present time.

In connection with Mr. Archer's statement, I would like also to ask about packing materials in a controlled temperature, a controlled atmosphere, using counter current methods to get alternate heating and cooling at moderately rapid rates.

Chairman Archer: Has anyone any remarks on the first question? That is, as to the usefulness of a high tensile malleable with relatively little elongation. I think that demand really has to come from the consumers and the malleable people have certainly considered it and have told me, many of them, that the customers don't seem to want it.

In regard to the tunnel furnace that I spoke of, if the castings are rather intricate and thin they are apt to need packing to support them; if it is a simple shape, they can probably be stacked one on top of the other and at moderate temperatures they wouldn't warp too much. Even in that tunnel proposition, the charge probably must be fairly heavy, that is, if the trucks are say four feet across and you load them to a height of three feet or four feet—that is a pretty small tunnel—yet a mass of that weight couldn't be heated and cooled very quickly. You have to wait for the points in the charge that are the farthest away from the temperature you want. If you are cooling and you want to cool below the critical range, you have to wait until the center is down, if you are heating, you have to wait until the center is up. If you apply a rapid rate of heating, the outside will be rather higher than you want it by the time the center is up. Those are the things that make that fluctuation look rather difficult, to me, at least.

Mr. Harder: In the production of gray iron castings, we frequently get hard spots corresponding to the original condition of white iron castings. I would like to ask the speaker what temperature he would use for the annealing of those hard spots.

Dr. Hayes: If those are due to massive cementite that never has been absorbed, then it requires either a long time at the ordinary temperature of about 800 degrees Cent. or a shorter time at much higher temperatures. As I say, I am not a practical man, and I would hesitate in giving advice. We know from our photographs that on our rapid methods, after we start the slow cool, there is practically no further disappearance of massive cementite, it stays as it is. The present accepted theory is that decomposition of combined carbon takes place from the solid solution, and the massive cementite remains intact. At those temperatures, about 800 degrees Cent. the rate of absorption of massive cementite into the solid solution is slow, and its transition over, that is, its rate of precipitation, corresponding to the graphite solubility value,

is also slow, so to eliminate hard spots, the hard spots are due to not enough time at the temperature. You see that slow cooling sort of irons out all the little imperfections. Too rapid or too short a space of time at the high temperature may hurt good material.

Chairman Archer: I think in the case of gray iron the problem is much more simple, because the carbon and the silicon are very much higher, and the rate of graphitization is very much faster than in the malleable castings. You don't have to use as high a temperature, or as long a time. I think the usual practice is about 1400 degrees Fahr. I don't know just how long, possibly two hours at 1400 degrees Fahr. and slow cooling will kill those hard spots. Pistons are sometimes annealed for about 6 or 8 hours at 1000 degrees Fahr. to remove hard spots and also to relieve internal stresses which might cause distortion. after machining.

Mr. Maloche: I have conducted a few experiments with the ordinary gray iron, and with the same mix and analysis and I found an anneal at 1450 degrees Fahr. for three hours could be replaced by an anneal at 1600 degrees Fahr. for 25 minutes. In running them through at that rate we got very good results, only occasionally we would get trouble with scaling, not warping,—they were very small castings, and not made for strength, but the only trouble they have is they scale occasionally. The 1600 degrees Fahr. anneal for 25 minutes seems to do the work.

Mr. Harder: I would like to ask a question about the annealing of gray iron castings where the temperature is in the range of 1400 to 1600 degrees Fahr. In some cases they have observed a marked growth in the size of the casting in that range. I would like to know if some of the men here have observed that, and at exactly what temperature that occurs, and what takes place there.

Mr. Maloche: I have noticed that at those temperatures, if the castings were carelessly left in the furnace for a longer length of time. say three or four heats, the growth was remarkable. But on a 25 minutes anneal at 1600 degrees Fahr. I have noticed no such growth. But if you leave it in the furnace for possibly two or three hours at those temperatures you will get it, as well as distortion.

Mr. Harder: That is in keeping with the experience I have had reported to me. They gave it a rather long anneal at the high temperature, and it distorted half to a quarter inch in a foot.

A RECORDING CHRONOGRAPH FOR THE INVERSE-RATE METHOD OF THERMAL ANALYSIS*

By H. J. French

ONE of the most useful methods of thermal analysis, whereby very small arrests may be detected in the heating and cooling of metals, is that known as the inverse-rate method in which the time interval required for a definite temperature change is plotted against the temperature. Its limited application has been due largely to the expensive equipment required, but in part to the lack of suitable recording apparatus for direct plotting of curves in order to eliminate the long and tedious processes involved in their preparation from data obtained with the usual types of chronographs.

A special recording instrument for such work, designed by Rosenhain[1], has been in use for some time at the National Physical Laboratory in England, but so far as is known by the author, this instrument has not been used in the United States and no others of a similar nature are available.

The equipment and procedure employed heretofore at the Bureau of Standards[2] has already been described in detail and is essentially as follows:

A small slotted specimen of the test metal, mounted on a thermocouple (one wire being platinum and the other wire 90% platinum, 10% rhodium) and placed in an evacuated silica tube, is raised or lowered at a definite and predetermined rate in a tubular electric resistance furnace which is mounted in a vertical position. The platinum heating coil used is restricted to the upper end of the furnace which has a relatively large thermal capacity compared to the sample being heated and is so constructed that a gradual decrease in temperature is obtained from top to bottom. Under such conditions the rate of temperature change to which the metal is subjected is dependent upon the rate at which the specimen is moved up or down in the heating unit. This is controlled by weights acting against an adjustable flow of oil moving a plunger in a cylinder. The flow of oil is regulated by a calibrated needle-valve and the plunger is connected to the tube which contains the test specimen.

The method employed with this equipment consisted in recording on the usual type of drum chronograph the time required for a definite temperature change in the specimen while temperature measurements were taken by means of the thermocouple and a dial potentiometer. The chronograph records were subsequently "counted" and the curve plotted by hand with time intervals as abscissa and mean temperatures during the intervals as ordinates.

In order to eliminate part of the expensive equipment required and at the same time reduce somewhat the work of preparing the graphs, Merica[3] proposed the use of stop watches to measure time intervals. This method eliminates the "counting" of chronograph records but it is still necessary to plot curves by hand and the ratio of time consumed in this operation to that actually employed in making observations remains quite large.

Obviously, the only satisfactory method for rapid production of in-

*Published by permission of the director of the Bureau of Standards.

1. W. Rosenhain: *Journal* of the Institute of Metals, 13, page 160; 1915.
2. *Scientific Paper* 348, Bureau of Standards, Washington, D. C.
3. Scientific Paper 336, Bureau of Standards, Washington, D. C.

A paper written by H. J. French, physicist with the Bureau of Standards, Washington, D. C.

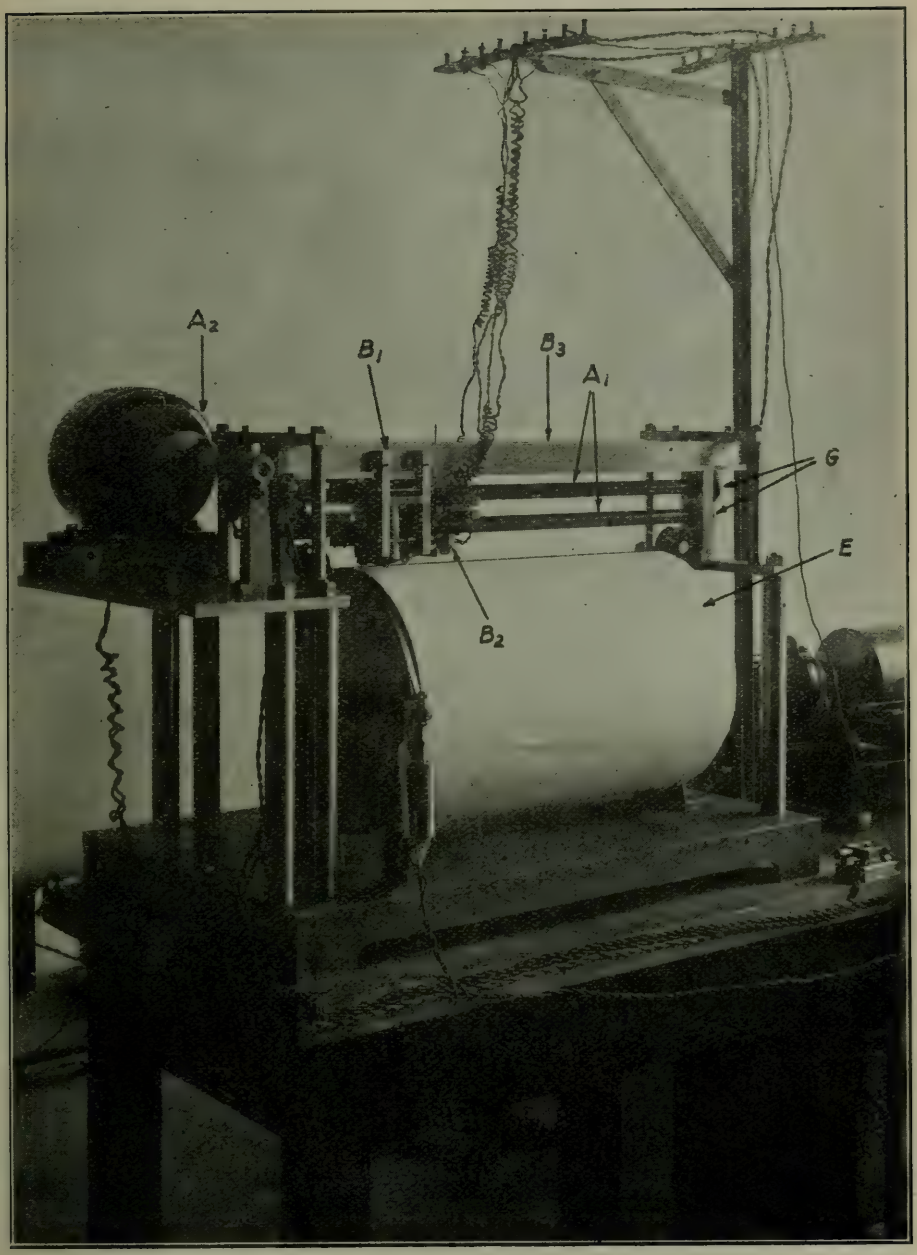


Fig. 1—Direct plotting chronograph for the inverse-rate method of thermal analysis.

verse-rate curves, particularly those covering a wide range in temperature when the plotting of 500 to 1000 points may be required as shown in Fig. 6, is by the use of a direct plotting chronograph, and to meet this condition the apparatus shown in Fig. 1 was designed. Its use for over eight

months in determining transformations in various carbon and alloy steels under varying thermal treatments has shown it to be well suited for both routine and research work and has resulted in a marked saving in time and effort with increased accuracy in the results obtained.

Description of the Direct Plotting Chronograph

The important parts of the apparatus, in addition to suitable mountings, are (a) propelling screws and motor drive; (b) carriages with pens and contact arms; (c) special switch; (d) electromagnets; (e) drum, carrying the record paper.

Two screws, shown at A_1 in Fig. 1, are driven at constant speeds in opposite directions by motor A_2 on which is mounted a suitable governor. The upper screw brings both carriages forward when engaged by their contact arms, while the lower one is used for return to their starting points or "zero positions." By means of the gear reduction shown at G and variation in the pitch of the two screws, the return of the carriages is made ten times as fast as their forward movement.

Two carriages (shown B_1 and B_2 in Fig. 1) are used. Each carries a pen and contact arms for engaging the propelling screws and runs on an overhead track, which, in each case is grooved to eliminate sideplay. In order to record continuously, time intervals, it is necessary that one carriage always be at its zero position or "base," ready to start forward, when the other is stopped, a record made of its position, and return to its starting point begun. To accurately measure such intervals requires very rapid reversal of the system and this is carried out with the aid of a special doublethrow "gang" switch controlling two sets of electromagnets. The mechanism of reversal is probably best illustrated diagramatically, a definite set of conditions first being assumed.

As indicated in Fig. 2, carriage F is moving away from its zero position (forward), the contact arm A_1 being engaged to the upper propelling screw. At the same time carriage R is returning to base at ten times the speed at which F is going forward. It will also be noted from Fig. 2 that the "reversing magnets" K_1 and K_2 are so arranged that when carrying current they throw the contact arms of both carriages against the "return screw," while when no current passes through their respective circuits the springs S_1 and S_2 hold these arms in contact with the "forward screw." It is therefore, possible by breaking the circuit k_2 and closing k_1 to reverse the system so that carriage R moves forward from its base and F returns. This change may readily be handled by a doublethrow switch, the moving arm of which travels through a small arc. By adding to it the necessary contact points it is possible to excite additional magnets operating auxiliary equipment, including the recording pens, which will give a record of carrage or pen positions at any instant that reversal of the system is desired.

The return of the carriages is quite rapid, so that the stops placed at their base positions are subjected to considerable impact. Tapered pins are used to raise their contact arms into a neutral position to prevent "stripping" the threads of the screws and there is, therefore, a decided tendency for the carriages to rebound. To avoid this and insure identical zero pen positions after each return additional magnets are placed at the base stops and hold the carriages in place until they again start forward. Thus six magnets are controlled by the special doublethrow "gang" switch which

is thrown from X to Y or Y to X, depending upon its position at the instant the operator desires reversal.

As the moving arm of the switch travels from Y to X, for example, pen P_2 is depressed and a record of its base position obtained. Because of the small width of contacts controlling the pen magnets the circuit p_2 is quickly broken and the pen raised, thereby preventing it being dragged along the paper. Simultaneously circuits k_2 and z_2 are opened, resulting in the

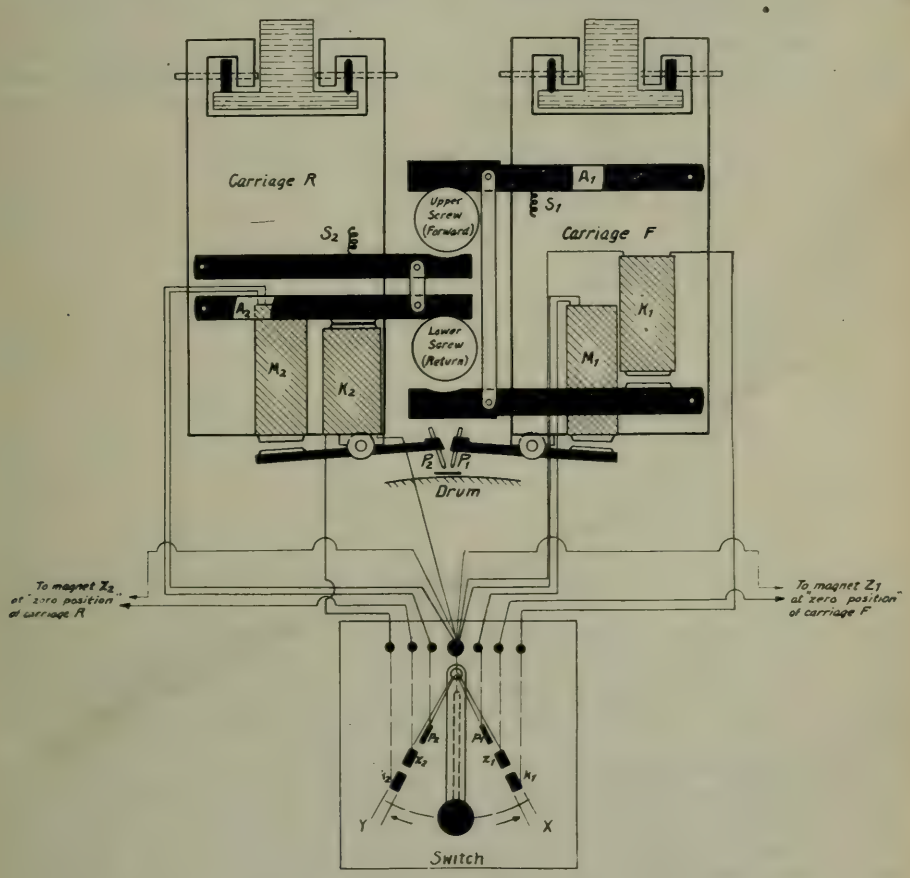


Fig. 2—Diagram showing fundamentals of design and operation of the direct plotting chronograph.

release of the carriage R by the base magnet Z_2 at the same time that the contact arm is released by magnet K_2 and pulled by spring S_2 against the forward screw. When the moving arm of the switch reaches contacts z_1 and k_1, the zero magnet for carriage F is excited and simultaneously the contact arm is thrown from forward into reverse. At the same instant the pen P_1 is depressed by its magnet and then quickly raised by the breaking of the circuit at p_1. This entire cycle of change, requires less than one-fifth of a second under ordinary conditions.

To plot time intervals as a function of temperature by means of the mechanism just described does not offer any special difficulties. Instead of a drum rotating at a constant and predetermined speed, such as is em-

ployed with the usual type of recording chronograph, one is required which can be moved a fixed distance whenever desired. If the distance between the line of travel of the two pen points is equal to x (Fig. 3) and the first time interval recorded in any run is made with pen B then it is not necessary to move the drum carrying the paper until after A has recorded the second interval. It should then be moved in the direction S a distance equal to 2x. This brings the first point of the curve, b, to the position b^1, the second point, a to a^1 and the third point which is again recorded by pen *B* over the position originally occupied on the paper by point b. The control of the drum movement can readily be handled by a ring gear and a simple mechanical device which is operated by an electromagnet, as shown in Fig. 1. As the two pens alternate in recording time intervals and rotation of the drum is only required after each second interval, control of the latter may be added to the special "gang" switch by placing an additional contact point on that side where the carriage B of Fig. 3 is thrown from forward into reverse. Thus time intervals are recorded as abscissae by the movement of pens along the axes of the propelling screws while temperatures are recorded as ordinates by means of the intermittent rotation of the drum.

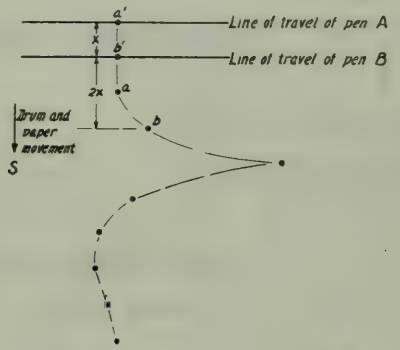


Fig. 3—Relation of drum movement to pen positions.

The procedure employed with this special chronograph is similar to that used with the ordinary type. The operator sets the potentiometer at successive values of e. m. f., differing by equal increments, usually 0.02 millivolt, but instead of pressing a contact key at the exact instant at which the galvanometer coil passes through its null position, throws the special switch which reverses the entire system.

Typical Curves Obtained

Reproduction of typical curves obtained by the use of the apparatus are given in Figs. 4, 5 and 6. Relatively minute thermal arrests, such as the A_2 transformation in pure iron (Fig. 4) which are not readily observed except when using accurate methods, are clearly shown. The characteristics of different transformations are also well preserved, as is illustrated in Fig. 6 where both "sharp" and "rounded points" appear. Likewise, equally good results are obtained when using rapid (Fig. 4) or slow (Fig. 6) rates of temperature change.

The curves are not produced automatically and are, therefore, still

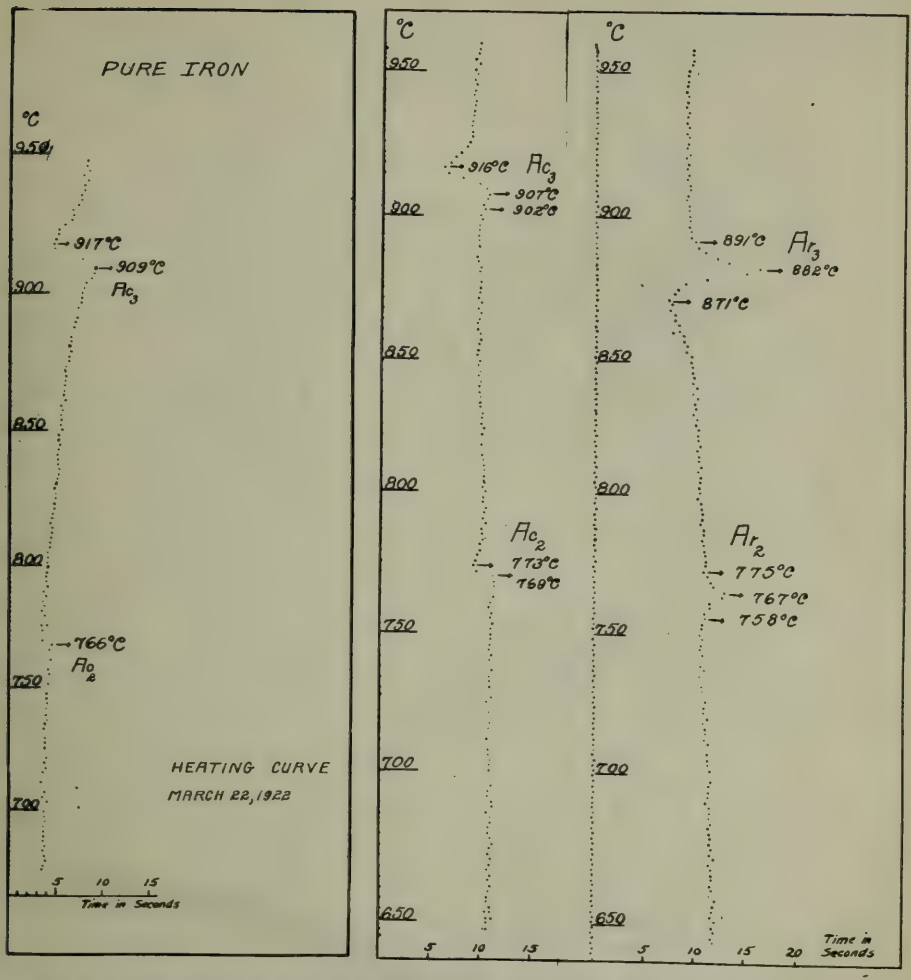


Fig. 4—Heating curve of pure iron obtained with the direct plotting chronograph. About 25 minutes required for the "run." Reproduction about one-third size. Fig. 5—Heating and cooling curves of copper steel containing carbon, 0.06 per cent; copper, 0.24 per cent. Reproduction about one-third size.

dependent upon the careful work of an operator. They are, however, less susceptible to errors arising purely from the "human element" than are curves prepared by methods employed in hand plotting as the "counting" of chronograph sheets containing several hundred observations and the placing of values so obtained upon finely divided cross section paper demands most painstaking and careful work for the elimination of errors.

Long and short readings, resulting from delay in throwing the switch as the galvanometer passes its null position, are not eliminated but are definitely shown by reason of the fact that the resulting points will be at equal distances and on opposite sides of the true curve. One of two examples of this are contained in Fig. 6. However, errors introduced in the plotting are avoided.

A desirable feature of the curves is the check obtained on the base

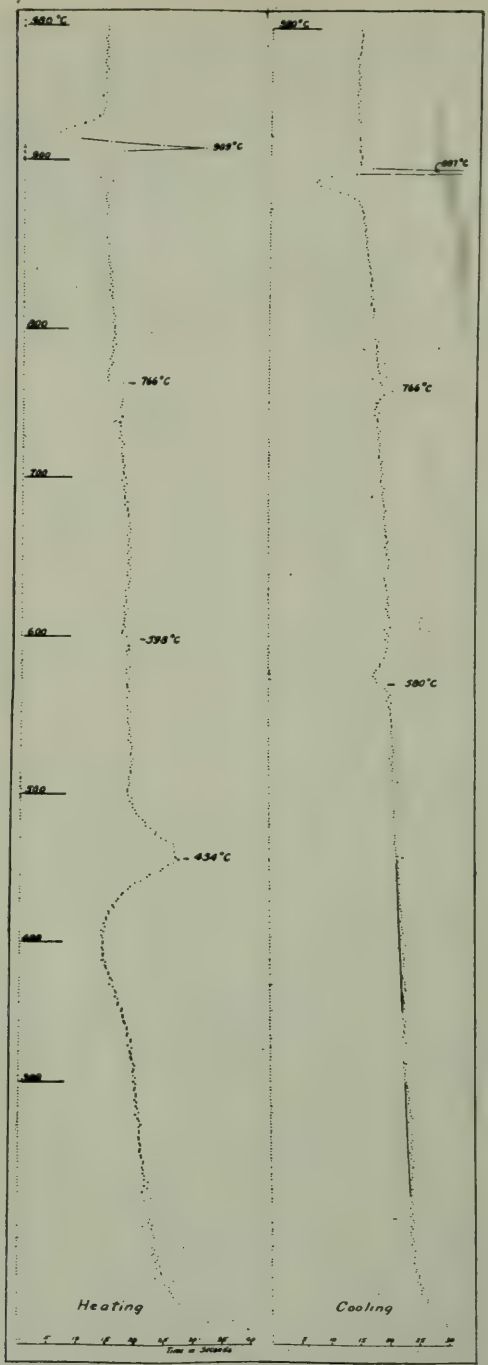


Fig. 6—Heating and cooling curves of electrolytic iron remelted under an atmosphere of nitrogen in a zirconium crucible and to which a small proportion of calcium has been added. Reproduction about one-fourth size.

position of both pens prior to recording each time interval. This was inadvertently introduced with the use of the reversing switch and equipment previously described, but is of considerable value in preventing introduction of errors due to a changing base line brought about by loosened carriage or pen parts or other causes.

Discussion of Constructional Features of the Instrument

Because of the varying magnitude of thermal transformations a high speed return of the pens is necessary. Usually long arrests are followed by very short intervals and a condition may obtain where insufficient time is allowed for one carriage to return to its base position before it is again required to start forward to record a subsequent interval. In general a ratio of 10 to 1 is sufficient though one or two cases have already been encountered where this was not so. However, it is questionable whether any additional information of value would be obtained by following completely such extremely large thermal effects, though they may readily be recorded by increasing somewhat the speed ratio referred to.

One of the important features of the equipment is the special switch, several types of which have been tried, as shown in Fig. 7. Type A was used originally and was generally satisfactory except for the rapid burning of the contacts which required considerable attention to insure satisfactory operation. A knife switch, such as type B, was tried but due to excessive arcing and inconvenience in operating it, was discarded. This type was replaced by C which proved to be the most desirable and has been adopted. It was recognized, however, that the early difficulties encountered were due to the relatively high current necessary for operating the magnets, as originally constructed and that by rewinding for lower current such undesirable effects would be largely eliminated.

The recording pens are different from those ordinarily employed. A two-color typewriter ribbon is stretched along the line of travel of the pens, which consist of small steel rods, rounded at the ends, and mounted in suitable holders. When depressed by their magnets, the pens strike the ribbon, which is close to the paper, leaving a small round dot. Thus the use of fountain pens or other types containing liquids which are not well suited to the service requirements in this instrument and which ordinarily require a good deal of attention, is avoided.

The original apparatus shown in Fig. 1 was purposely made larger than necessary in order that adjustments and such changes as might be desired could more readily be made in the laboratory but there is no reason why a second model should not be made smaller and portable. The width and diameter of the drum may be reduced. Also, the carriages, propelling screws and many of the mountings are larger than required, but an adequate driving force must be retained as constant speed of rotation of the screws is one of the essential features of satisfactory operation. Engaging the contact arms is accompanied by impact, and results in sudden changes in load which must be absorbed by the motor and governor without noticeable speed change in the recording pens.

It is not necessary to restrict the use of the apparatus to the special furnace previously mentioned, as entirely satisfactory curves for ordinary purposes may be obtained with any heating unit in which a moderately uniform rate of temperature change can be produced and under such conditions determination of transformations may be made in a very short time. The curve

shown in Fig. 4 was obtained in about 25 minutes after the test sample was prepared by heating it in air in a small and inexpensive resistance furnace.

Certain modifications or additions to the original apparatus shown in Fig. 1 are now in progress. These include the installation of a simple mechanism for moving the typewriter ribbon with the drum in order to distribute the wear resulting from pens repeatedly striking within a narrow zone; a shifting device for more readily changing the record from black to red, instead of interchanging the positions of spools carrying the two-color ribbon; a "base shift" for the drum so that heating and cooling curves may be obtained side by side instead of as in the original apparatus, one over the other unless the paper position was changed.

The instrument described serves the same purpose as that in use in the National Physical Laboratory previously referred to. However, two pens are used as suggested by O. F. Hudson[4] thereby obviating the necessity of providing compensation for the time required for a single pen to return to its base position. Also, the use of a typewriter ribbon and solid steel bars for producing the records gives much less trouble than any type of pen already devised for the use of liquids in producing curves by a series of detached markings, and the use of a special doublethrow "gang" switch, which is not much more troublesome to operate than a key, has simplified the electrical control. It is believed the new instrument is more simply and, therefore, more cheaply constructed.

The author takes pleasure in making acknowledgement to J. Ludewig, mechanician, instrument shop, Bureau of Standards, who contributed so largely to the success of this instrument by working out the mechanical details from incomplete drawings and sketches containing principally the fundamental features of design; and to Misses I. Wymore, assistant chemist, and M. Preble, senior aid, who have handled the laboratory work in connection with the trial of the apparatus.

4. See footnote No. 1.

THE STRUCTURE AND RELATED PROPERTIES OF METALS

By Henry S. Rawdon

Abstract

This paper dealing with the structure and related properties of metals is divided into four main parts. The first part is the introduction which outlines in some detail the purpose of the paper stating that in order for one to be familiar with the reasons for variations in the properties of metals under different treatments a knowledge of the structure of the material is indispensable. Nonferrous as well as ferrous alloys are discussed.

The second part dealing with the structure of metals, develops the topics of macrostructure, conditions affecting structure, chemical composition, temperature, grain growth, phase changes and the working of metals.

The third part develops the effects of the structure of alloys upon their properties. The topics in this division deal with hard and soft constituents, soft ductile constituents, orientation of test specimen with respect to material under test, coarsely grained metals, physical state of microscopic constituents, chemical properties, solubility of tempered steels and corrosion.

The last part discusses the applications of the microscopy of metals. The author discusses the relations of microscopy to the heat treatment of metals showing that microscopy is a very valuable aid in the control of metallurgical operations and products. In the investigation of materials which have failed in service the microscope has proved invaluable . A number of examples of the deterioration of metals and alloys in service are given.

Introduction

TO ANYONE interested in the WHY and WHEREFORE of the behavior of metals, for example, the reasons for the variations of properties under different treatments or the detection of evidence leading to an explanation of the deterioration or failure of metals in service, a knowledge of the structure is indispensable. This line of study and investigation is probably the most fascinating of all the various subjects which we group together under the heading of *metallurgy*. However, if any method or line of investigation is to hold its own, particularly in a commercial laboratory, IT MUST PAY ITS WAY and it is, therefore, the practical value of the microscopy of metals that has been emphasized in the following discussion. Many of the illustrations used have been purposely chosen from other alloys besides steel in order to emphasize the fact that steels form only one group in the general classification and are subject to the same laws as are all alloys. Largely on account of the preponderating industrial importance of steels, the idea has formed in the minds of some, particularly those whose work deals with only a few types of materials, that the convenient distinction usually made

A paper presented before the Philadelphia chapter of the society. The author, Henry S. Rawdon, is physicist with the Bureau of Standards, Washington, D. C.

between ferrous and nonferrous alloys as a convenience for classification and discussion is a very real distinction and, as a result, steels are apt not to be regarded in the same light that *alloys* are.

The physical properties of an alloy are much more closely related to the minute structure of the material than they are to the ultimate chemical composition. Today no one questions the value of chemical analysis in metallurgical work but the metallographic examination when properly interpreted may be of far greater value than the chemical, for example, in explaining the properties and predicting the uses of the finished product. The nature of the various microconstituents comprising the alloy and their relative size and distribution, the occurrence of extraneous substances or *inclusions*, the structural effects of thermal and mechanical treatment together with other features revealed by the examination are factors of supreme importance in determining the properties of the material.

All tests of metals are for the general purpose of determining the suitability of the material for some specific use, the mechanical properties are therefore in many cases, the ultimate criteria. As in the case of chemical analysis the metallographic examination can be made of inestimable service in mechanical testing. The selection of specimens may determine absolutely the validity of any conclusions drawn from tests. Not only may the small test specimens be properly taken so as to represent the larger mass of metal but the results obtained in the test may be most properly interpreted in terms of the structure of the material and for purposes of comparison it is necessary the materials be in the same structural condition.

A knowledge of the chemical composition is essential to a full understanding and interpretation of the structural condition of any metal or alloy and to a somewhat lesser extent mechanical testing is also. Conversely, a knowledge of the structural condition supplements and explains the results of the other two methods of testing. All three are mutually interdependent and necessary for a full understanding of the properties of any metal.

Structure of Metals

The term STRUCTURE when employed with reference to metals and alloys is used in a somewhat restricted sense. The metal microscopist ordinarily does not use this term to include such structural features as the minute crystalline structure, the atomic arrangement and such other fundamental features of matter as may be revealed by suitably refined means. The term is generally used to include those features, which can be revealed by the use of an instrument having no greater refinement than that of the modern compound microscope.

Macrostructure

In exactly the same way that a knowledge of the anatomy of the human body must be used as a background into which to fit the information gained by a study of the minute features of the various tissues which make up the body, just so is the knowledge of the gross structure of metals and alloys as gained from a macroscopic examination very helpful and necessary in understanding properly the minute features revealed by the microscope. A discussion of the macrostructure of metals could easily constitute the basis of an entire evening's talk. A few typical illustrations only will be considered.

The principal use made of macroscopic examination of steels is probably the detection of nonhomogeneity of composition, the well-known SULPHUR PRINT being the most familiar illustration. Etching of some kind is usually

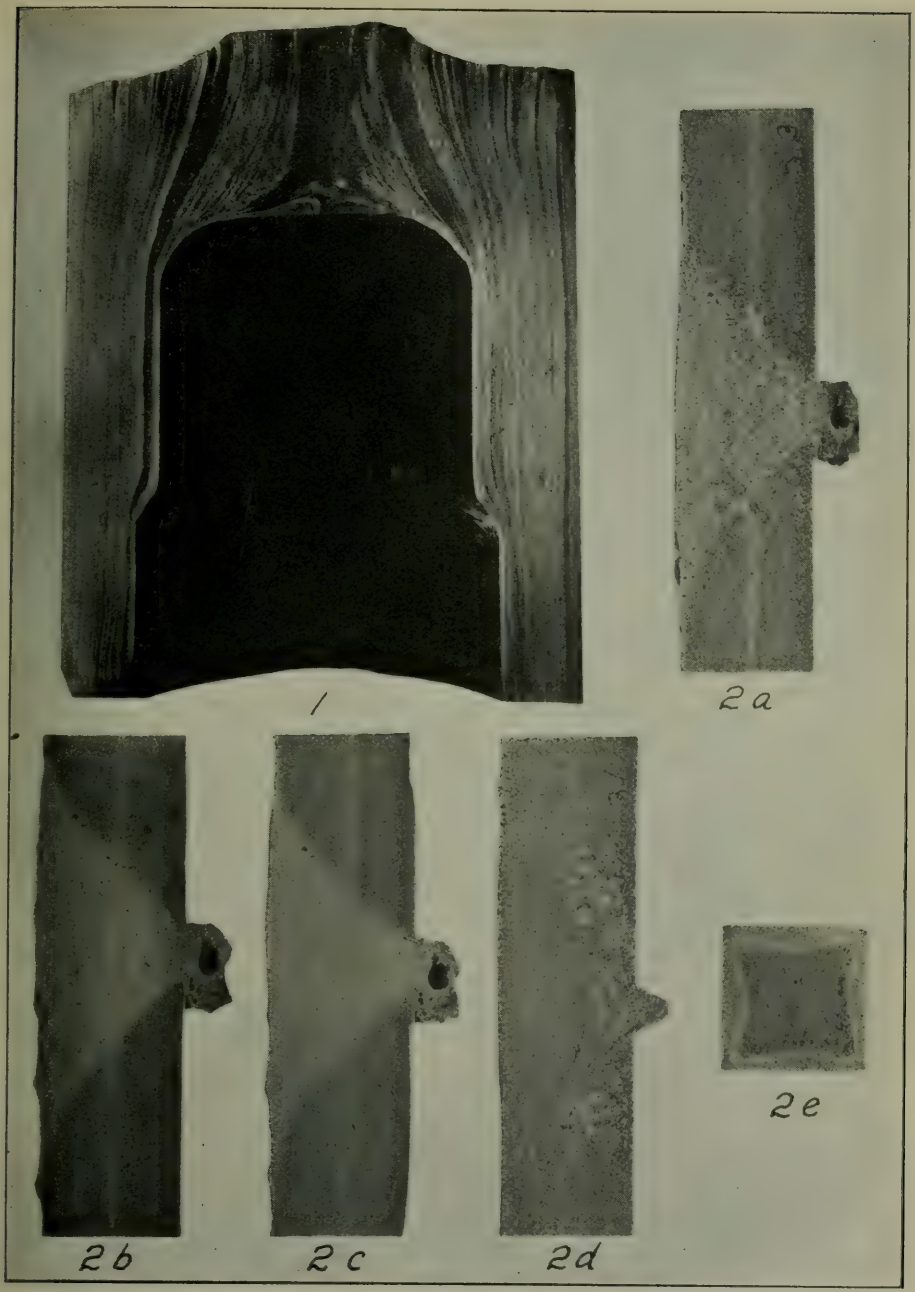


Fig. 1—Macrostructure of forged steel (portion of shrapnel shell) revealed by etching a longitudinal section with cupric chloride (Stead's reagent). × 4/5. Fig 2a—Specimen of oxyacetylene welded steel plate etched with aqueous solution of ammonium persulphate. Fig. 2b—Same as Fig. 2a, etched with aqueous solution of copper ammonium chloride. Fig. 2c—Same as Fig. 2a, etched with 2 per cent alcoholic nitric acid. Fig. 2d—Welded steel plate, similar to Fig. 2a, illustrating overheating of the plate, etched with ammonium persulphate. Fig. 2e—Cross-section of a bar of segregated steel, etched with ammonium persulphate. These photographs illustrate the advantages of the use of ammonium persulphate as an etching reagent. All photographs full size, excepting Fig. 1.

a prerequisite for revealing nonhomogeneity, one of the well-known cupric reagents is often employed for the purpose (Fig. 1). The use of such a reagent has an additional advantage in that it often reveals many things concerning the previous history of the material, particularly its mechanical working. Phosphorus diffuses in iron or steel with extreme slowness and hence the streaky appearance caused by the non-uniform distribution of this element persists throughout the period of mechanical working of the material and thus records the story of the deformation the metal had to undergo. This is often of advantage in determining whether certain defects had their origin before, during, or after the process of mechanical working. In other alloys, similar persistent features may tell the same story.

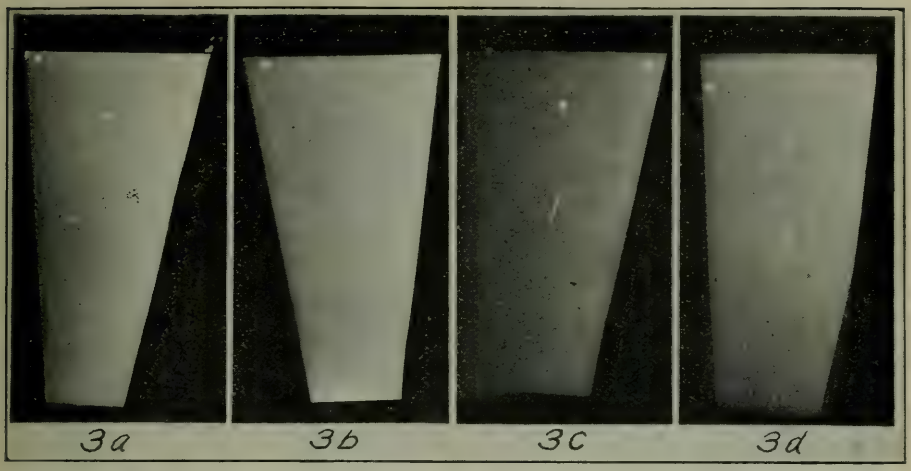
Deep etching of steel is an easy and convenient method for revealing many of its structural features. Such an etching often tells much concerning the chemical homogeneity, the crystalline condition, and the physical soundness of the material. A method which has recently been described by the Bureau of Standards for revealing crystalline heterogeneity of iron and steel depends upon etching by means ammonium persulphate solution. (Fig. 2). This has the advantage that it does not roughen the surface as deep etching does, yet reveals the crystalline condition in a very striking manner. Its use for copper alloys has been recognized for some time.

For revealing the physical unsoundness of metals, special methods are often necessary. Thus the porosity of aluminum alloy castings may often be detected by soaking the sectioned and polished specimen in highly colored alcohol (picric acid is admirable for the purpose) quickly wiping and drying the surface of specimen and then permitting the alcohol contained within the tiny cavities to exude and evaporate leaving a colored spot which will make the location of each internal cavity or pore.

Radiographic examination has been successfully employed for the examination of the physical condition of interior of metals if specimens are of suitable size. The detection of additions of lead alloy or similar material to full cavities in aluminum alloy castings may be made by this means. For steel, the method had been successfully used in locating internal defects, such as FLAKES (internal discontinuities) as well as grosser imperfections such as blow holes. In general the specimen, if steel, must not exceed ½ inch in thickness. The method will probably never be used as a routine means of examination on account of its cost, danger of operation, and its inherent limitations. Fig. 3 shows an application of its use in following the persistence of certain internal defects during a series of treatments used for the purpose of eliminating them.

A special method which is very successful in locating cracks or other discontinuties which appear on the surface of a steel specimen is a magnetic one. The polished specimen after being magnetized is bathed in a light oil (kerosene) carrying fine iron dust in suspension. This method has found practical every day application at the Bureau of Standards in the inspection of gage-blocks after the hardening process. A great deal of time was saved in this way by rejecting specimens showing surface cracks by this means before subjecting them to the tedious lapping operation (Fig. 4). It has also been used successfully in locating interior fractures in rolled and forged steel products such as rails. These internal fractures may be revealed by other means, such as deep etching, but the magnetic method appears to be the only suitable one which does not alter, in any way, the character of the surface of the specimen.

The mechanical condition of a metal, that is, its state with respect to



Figs. 3a-3d—Defects, "flakes," in forged gun steel revealed by radiographic examination. Approximately × ¾. A radiograph of the specimen was taken after each of the treatments listed below. The steel plate ¼-inch thick, containing three holes (white spots in radiographs) drilled partly through for reference points was placed so that the direction of the X-rays coincided with the plane of the defect. Each white line in the radiograph represents a "flake." Fig. 3a—Forging, as received. Fig. 3b—Same as Fig. 3a after annealing for 30 minutes at 900 degrees Cent., furnace cooled. Fig. 3c—Same as Fig. 3b, heated 30 minutes at 900 degrees Cent. and quenched in oil. Fig. 3d—Same as Fig. 3c, heated 30 minutes at 1050 degrees Cent., was quenched in oil. The successive radiographs indicate the persistence of the defects after the thermal treatments given the material. Exposure: 9-inch spark, 2 millimeters, 7 minutes.

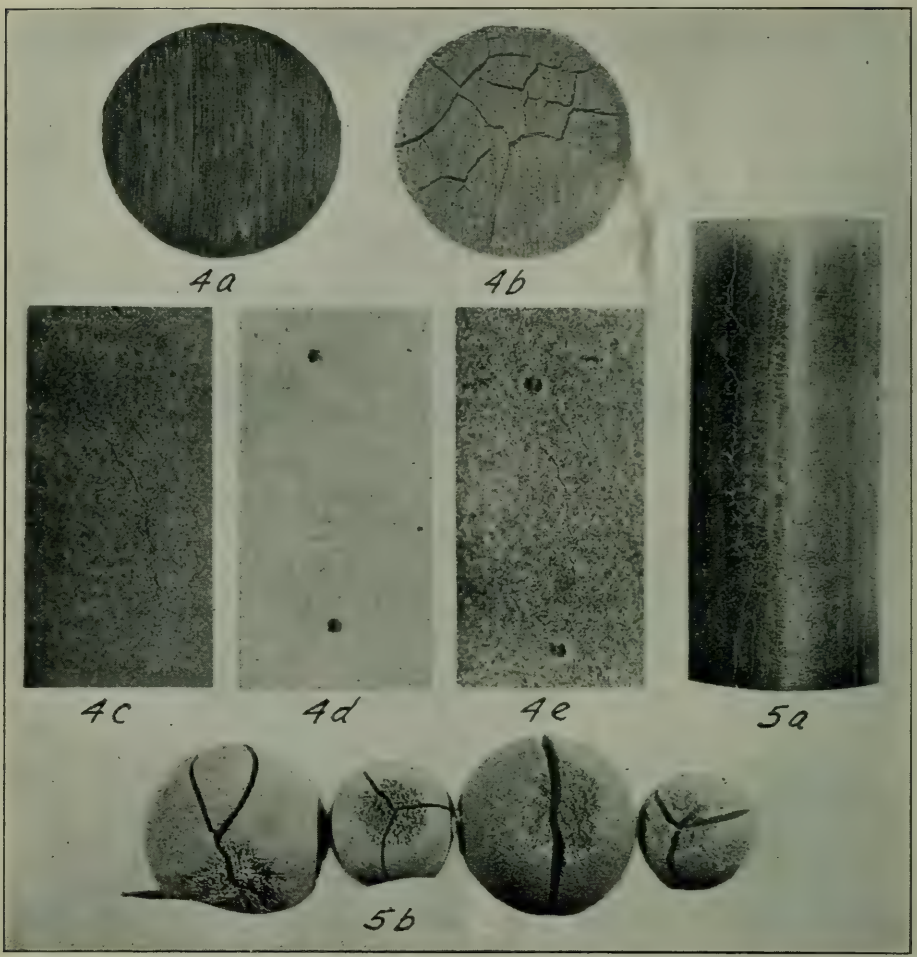
internal stresses has much to do with the stability of such material in service. Often, as a result of the action of certain intense etching reagents, materials which are highly internally stressed either as a result of mechanical work or thermal treatment received can be made to fail in a manner closely resembling what would probably have occurred spontaneously later in service. Fig. 5 shows the behavior of two types of materials after etching to reveal the mechanical nonuniformity. This defect termed SEASON CRACKING is most common in brass and some other copper alloys but the same conditions may exist in steel after very severe treatment either mechanical or thermal.

Conditions Affecting Structure

The principal conditions which affect and determine the structure of metals are, chemical composition, temperature, and mechanical treatment; chemical composition being doubtless the most important.

Chemical Composition

To discuss adequately the structural variations due to composition would necessitate a lengthy review of the PHASE RULE. A brief reference to the various typical copper-zinc alloys will suffice as an illustration. Fig. 6 shows the structure of the alloys corresponding to the different structural fields of the copper-zinc constitutional diagram. The structural changes corresponding to variations in the relative amounts of the two component metals are very evident. One fact which is very plain from the micrographs, though indicated also in the diagram, is the alternation of homogeneous (one constituent) and heterogeneous (two constituent) structural fields. This, of course, is merely one of the observed facts which are summarized in the concise statement familiar to us as the phase rule. This fact is often of importance in deciding whether certain features observed in the structure of an



Figs. 4a-4e—Physical unsoundness of steel revealed by magnetic examination. Fig. 4a—Roughly polished surface of a precision gage block. × 1½. Fig. 4b—Same as Fig. 4a magnetized and bathed in kerosene containing fine iron dust in suspension; a network of fine "hardening" cracks is revealed. × 1½. Fig. 4c—Section of steel from head of a rail containing internal fractures, revealed by method of Fig. 4b. × 3. Fig. 4d—Same specimen as Fig. 4c after locating the defect by a punch mark at each end. After removing the iron dust no trace of the discontinuity could be seen. × 3. Fig. 4e—Same specimen as Fig. 4d retreated as given in Fig. 4b. × 3. Fig. 5a and 5b—Mechanical nonuniformity of wrought metals revealed by deep etching. Fig. 5a—Section of a 1-inch manganese bronze rod etched with an acidulated aqueous solution of mercurous nitrate (65 grams, mercurous nitrate, 15 cubic centimeters, nitric acid per liter). × 1. Fig. 5b—Hardened steel balls which split open when deeply etched with concentrated hydrochloric acid.

alloy are due to traces of a second constituent or to other causes. A more familiar illustration of the variations in structure caused by slight composition changes in a binary alloy is that of annealed carbon steel as shown in Fig. 7. The range covered by these micrographs is only a relatively small part of the complete diagram, the variations in structure are very pronounced, however, although we are dealing with the same two phases throughout. The pronounced difference corresponding to relatively slight changes of composition render the estimation of the percentage composition from the appearance of the structure very easy and rather accurate—a valuable sup-

plement to chemical analysis by which may be shown variations in composition which the ordinary methods of sampling do not permit chemical analysis to detect. This application of the microscope in the study of segregated steel is familiar to all.

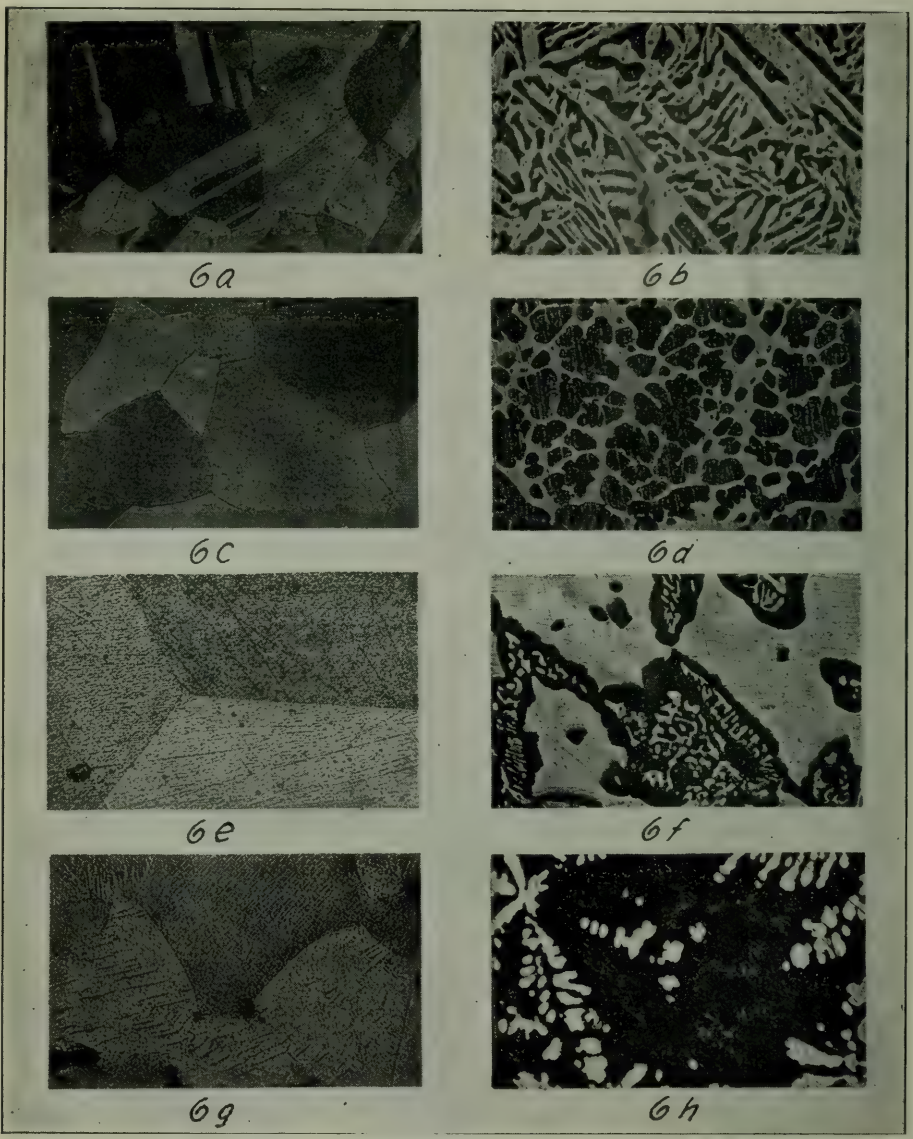
It often happens that metals and alloys show certain features of structure which are best described as being due to small inclusions of foreign material. Such enclusions, however, are often foreign only in the sense, that they are nonmetallic. They are a necessary result of the metallurgical process used for the preparation of the material. The everpresent slag of wrought iron is an example. Such slag threads are characteristic of this material and their presence or absence is often used as a criterion in disputed cases in deciding upon the nature of the material. The foreign inclusions may also result from additions made to the metal in course of preparation for improving its properties by some chemical reaction, for example, deoxidation and similar reactions. The products of the reaction are often retained in part by the metal after solidification and form a characteristic feature of the structure. Fig. 8 shows an inclusion in steel which resulted from an addition of titanium to the metal. The pink color and shape are quite characteristic of inclusions of this kind.

Some of the foreign inclusions are under certain conditions decidedly injurious to the metal in which they occur, in that, they render it of inferior mechanical properties. Sulphur in steel is a well-known example of this. In the form of ferrous sulphide, because of the form in which it is distributed, that is, as thin films enveloping the grains, it renders the steel almost unworkable at a red heat. Fig. 9 shows the characteristic appearance of the sulphur in steel when in the form of ferrous sulphide and also when this has been converted into manganese sulphide after proper treatment. The inclusions of manganese sulphide are not particularly harmful in the metal, that is, no more so than any similar inclusions are.

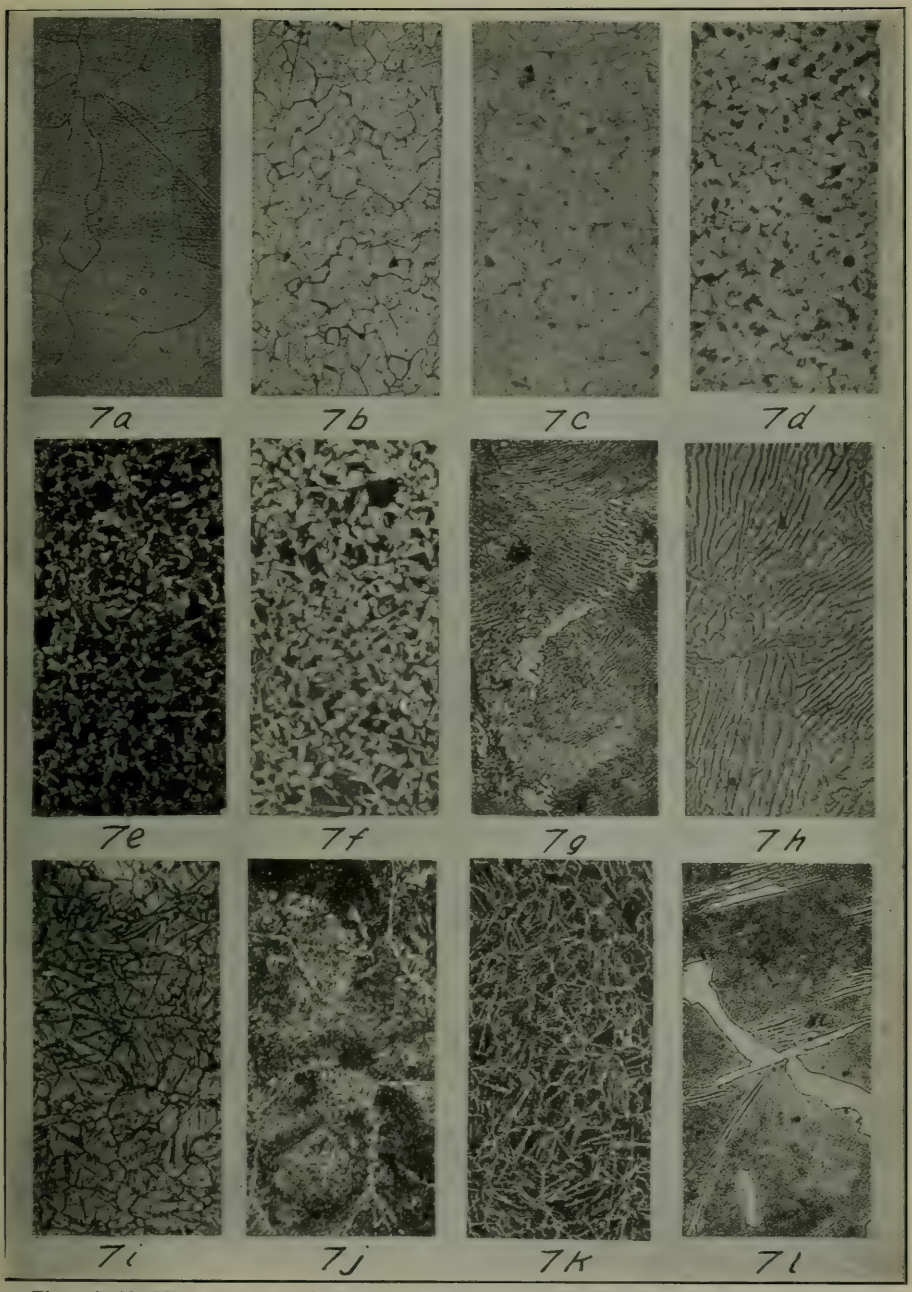
Temperature

The temperature to which a metal or alloy is heated, after it has been formed, has in most cases a marked influence upon its structure. These structural changes dependent upon heating may be conveniently classed as equilibrium changes, grain growth, and phase changes.

Practically all metals and alloys when cast, even upon slow cooling are far from being in a condition of structural equilibrium such as the phase rule predicates for the given conditions of composition and temperature. Metals, unless exceptionally pure and alloys normally show a cored or dendritic structure when in the cast state. This is a natural consequence of the selective process of freezing by which they solidify. In each crystal a branching or tree-like core which is relatively rich in the element of highest melting point is first formed and non-soluble impurities collect and constituents of lower melting point form in the interstices between the branches, the average composition of the material at such points being quite different from that of the CORE. When an alloy showing such a CORED structure is heated for a time at a relatively high temperature the principal effect is to erase the structural pattern by allowing diffusion to take place within the body of each crystal so that chemical homogeneity is approached. Unless the material has been subjected to other conditions, such as straining by mechanical deformation or its equivalent, excessively rapid cooling from a very high temperature, as well as phase transformations, change of grain-size in a cast alloy does not take place upon heating. The principal effect



Figs. 6a-6h—Microstructure of the principal types of alloys of the copper-zinc series. × 100. Fig. 6a—Alpha brass, annealed after cold work, etched with acidified aqueous solution of ferrite chloride. Fig. 6b—Alpha-Beta brass, hot-rolled, yellow matrix of beta containing reddish figures of alpha; etched with a dilute solution of sulphuric acid containing potassium dichromate. Fig. 6c—Beta brass, cast, golden yellow in color; etched with an ammoniacal solution of copper ammonium chloride. Fig. 6d—Gamma brass, cast, yellow matrix of beta containing silvery gray crystallites of gamma; etched with aqueous solution of ammonium persulphate. Fig. 6e—Gamma brass, cast; silvery gray in color, hard and brittle; etched as in Fig. 6d. Fig. 6f—Gamma-epsilon brass, cast; matrix of gamma containing the eutectoid of gamma and epsilon; etched as in Fig. 6d. Fig. 6g—Epsilon brass, cast, slightly purple when etched; etching reagent ammonium hydroxide and ammonium persulphate. Fig. 6h—Epsilon-eta brass, zinc-rich matrix of eta containing bright unetched crystallites of epsilon, etched as in Fig. 6d.



Figs. 7a-7l—Microstructure of typical annealed iron-carbon alloys (steels) illustrating the effect of variations in carbon content upon structure. Fig. 7a—Ferrite, electrolytic iron melted in vacuo. Figs. 7b-7g—Inclusive. Steels of ferrite-pearlite structure containing progressively increasing amounts of carbon as follows: Fig. 7b, 0.03 per cent. Fig. 7c, 0.07 per cent; Fig. 7d, 0.24 per cent; Fig. 7e, 0.32 per cent; Fig. 7f, 0.59 per cent; Fig. 7g, 0.68 per cent. Fig. 7h—Eutectoid steel. 0.85 per cent carbon. Fig. 7i-7l inclusive. Steels of pearlite-cementite structure containing progressively increasing amounts of carbon as follows: Fig. 7i, 1.14 per cent; Fig. 7j, 1.14 per cent; Fig. 7k, 1.45 per cent; Fig. 7l, 1.70 per cent. × 100 except Figs. 7g, 7h and 7j, × 500. Etching reagent; 2 per cent alcoholic solution of nitric acid except Fig. 7i for which boiling alkaline solution of sodium picrate was used.

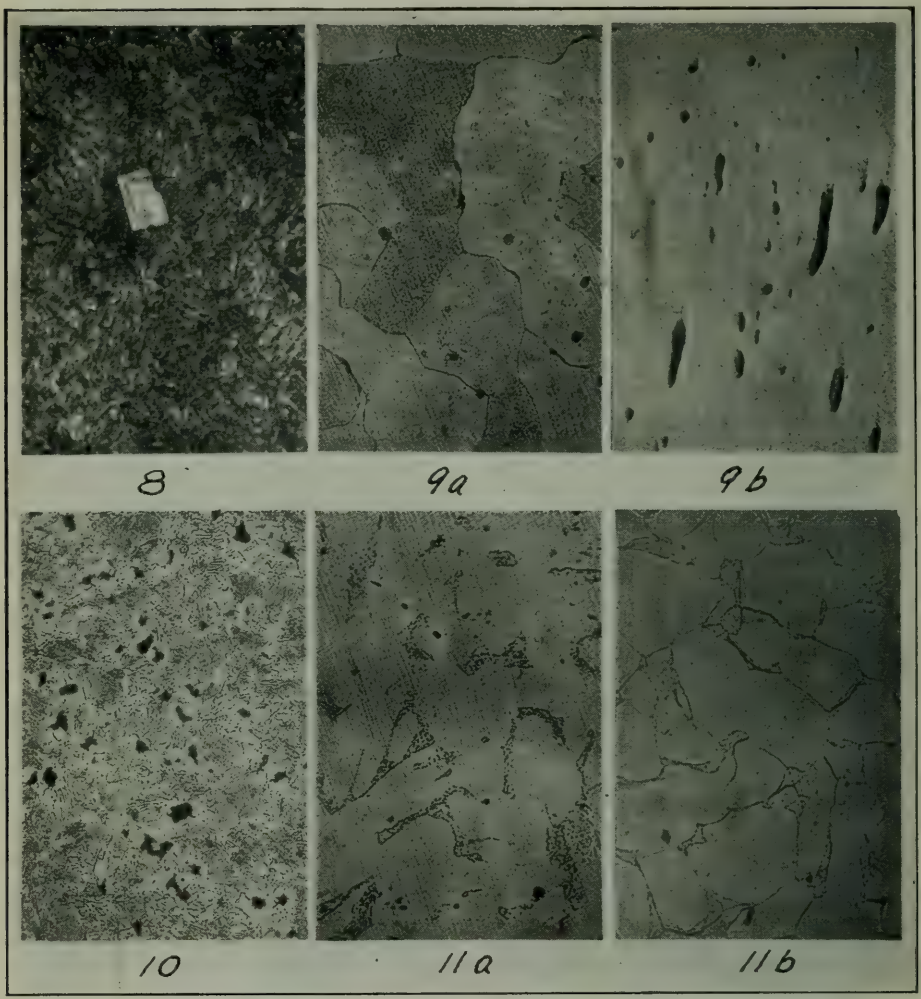


Fig. 8—Characteristic appearance of an inclusion caused by the addition of titanium to steel, × 1000. Etching reagent, 2 per cent alcoholic solution of nitric acid. Figs. 9a-9b—Microstructure of low-carbon steel illustrating the forms in which sulphur may occur. Fig. 9a—Longitudinal section of the segregated center of a 2-inch round bar intended for chains. It was impossible to forge and weld the material satisfactorily on account of the films of ferrous sulphide enveloping the grains, × 100. Etching reagent, 2 per cent alcoholic solution of nitric acid followed by hot alkaline sodium picrate. Fig. 9b—Longitudinal section of steel rod intended for use in an automatic lathe. The sulphur is in the form of isolated globules of manganese sulphide. × 100. Fig. 10—Microstructure of high-carbon steel in which graphitization has occurred. This is a tool steel, 1 per cent carbon, showing specks of graphite which have formed at the expense of the combined carbon; each speck of graphite is surrounded by an area of ferrite, percentage of graphite, 0.51 per cent, × 100. Etching medium, 2 per cent alcoholic solution of nitric acid. Figs. 11a-11b.—Microstructure of 0.18 per cent carbon steel as it exists at ordinary temperatures and at relatively high temperatures (basis of heat treatment). Fig. 11a—Pearlite-ferrite structure of the material at ordinary temperatures, revealed by etching with 2 per cent alcoholic solution of nitric acid, × 100. Fig. 11b—Same specimen as Fig. 11a, high-temperature structure revealed by heating the polished specimen in vacuo 30 minutes at 750 degrees Cent., above the A_1 transformation, and cooling in vacuo. A pronounced volume change, which is opposite in its character to that caused by heat alone, occurs in the steel during its transformation at the critical temperature. The deformation of the polished surface due to this change in volume, reveals the extent to which the austenitic solid solution resulting from the transformation of the pearlite merged with the ferrite, has progressed. × 100.

of the heat upon the chemically unhomogeneous cast material is to render it more nearly uniform in its composition by permitting diffusion, and in some cases solution of certain constituents, to occur.

Another effect of heat is the decomposition of a compound, as is illustrated by the formation of graphite from cementite during the heating of white cast iron and in some cases in high-carbon steels. (Fig. 10).

Grain Growth

The most striking change occurring in the structure of metals and alloys upon heating is the increase in grain size which often occurs. Such a change in grain size, usually necessitates a preliminary straining of the material. Cast alloys, at least those which involve no phase change upon heating, will show no increase in grain size even after several months' heating unless the material has been strained in some way. Since so many metals and alloys are subjected to mechanical work of some kind in their fabrication or to other conditions in special cases which bring about grain growth upon subsequent heating, the fact is often lost sight of that grain growth is not the simple result of heating only, other conditions are necessary to bring it about.

The increase in grain size which results in a steel bar by improper annealing is only too familiar. The distortion of the material which occurred in the rolling of the metal as well as the fact that the material is subject to a phase change upon heating accounts for the pronounced grain growth which occurred upon heating. A coarsely-grained condition in metals is usually regarded as very undesirable and particularly so in metals which may be subjected to shock or similar conditions in service.

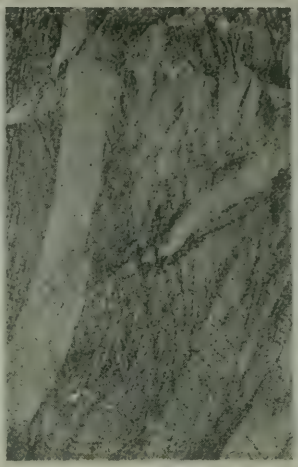
Phase Changes

In a great many alloys, pronounced structural changes occur upon heating to certain definite temperatures which of course vary with the different alloys under consideration. Such changes are to be ascribed to phase changes or transformations within the material. By quickly cooling an alloy which exhibits such changes, from a temperature somewhat higher than that at which the transformation occurs, the structure normally existing only at the higher temperature persists to a large extent, in the material at room temperature, the alloy being in a state of unstable equilibrium.

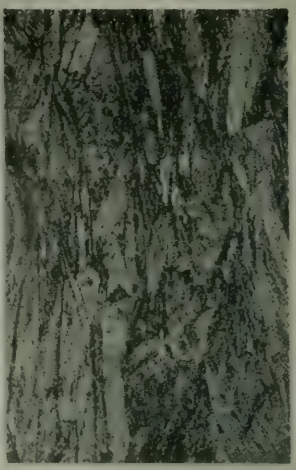
This fact is of very great industrial importance, the art of heat treatment of alloys, particularly steel, for high mechanical properties depends upon this fact. Fig. 11 shows the structure of a low carbon steel as usually observed and the structure of the same as it exists at a temperature somewhat above the first or A_1 transformation, as recorded by a special method of heat-etching by heating the polished specimen in vacuo. The definite boundary separating the austenite resulting from the transformation of the pearlite from the ferrite matrix may be plainly seen.

Phase changes or transformations in alloys are accompanied by energy (heat) manifestations. Hence it is much easier to investigate and establish the temperature at which the changes occur by the relatively simple means of THERMAL ANALYSIS rather than by the tedious and complicated methods necessary for the determination of the high-temperature structure of the material. Thermal analysis may be regarded then as the convenient means for demonstrating the structural changes which occur in alloys upon heating as well as the energy changes which accompany them. It may be noted, however, that some energy changes have been observed for which any pos-

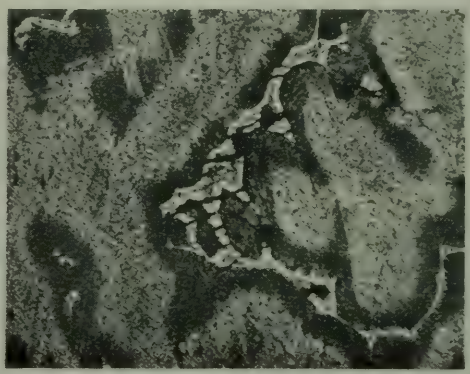
12 a



12 b



12 c



13

Figs. 12a-12c—Microstructure of brass illustrating progressive stages in the crystalline distortion produced by cold-working. × 100. Figs. 12a, 12b and 12c show three stages in the crystalline distortion of cartridge brass (approximate composition, copper 70 per cent, zinc 30 per cent) by cold-working the alloy. The series of parallel lines within any one crystal represents the planes along which the metal slips. They are of the nature of "slip bands" but persist after etching. Etching reagent, ammoniacal solution of copper ammonium chloride. Fig. 13—Microstructure of cast zinc-bronze which has been stressed in tension. × 250. The stress was applied at right angles to the cracks which formed in the hard brittle constituent of the alloy; approximate composition of alloy, copper 68 per cent; tin, 10 per cent; zinc, 2 per cent. Etching reagent, concentrated ammonium hydroxide.

sible accompanying structural change is so minute as to be beyond the range of the methods now used for observing the structure of metals.

Working of Metals

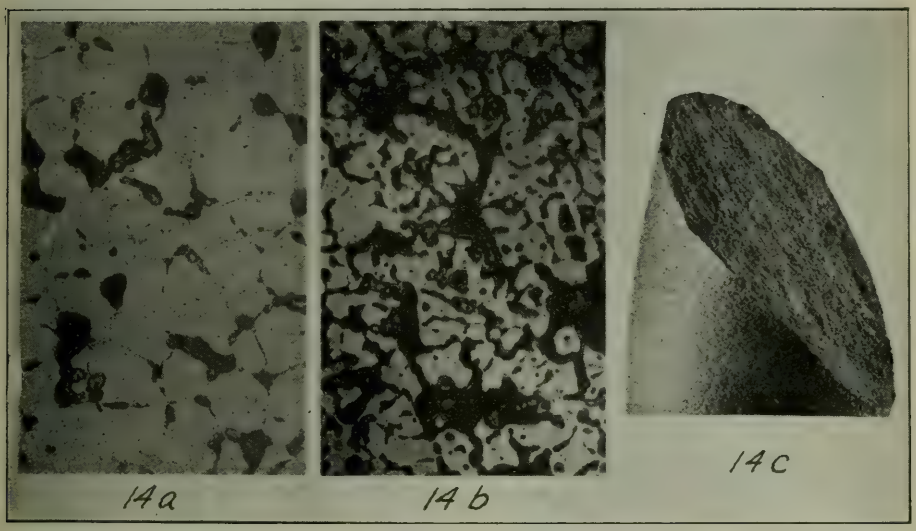
One of the most potent factors affecting the structure of metals and alloys is the amount of mechanical working received during fabrication after casting. Aside from the part played by the straining of metals in causing recrystallization and grain growth upon subsequent heating as explained above, the structure of the metal is often profoundly changed by the deformation of the material. Thus sections of a metal parallel to the direction of working will differ very materially in their appearance from those perpen-

dicular to the same. Fig. 12 illustrates how the deformation or change of crystal form is brought about in cartridge brass by means of an internal slip or FAULTING within the individual crystals along definite planes. These FAULTS persist in the crystals and are revealed when the metal is etched, and are not to be regarded necessarily as discontinuities within the crystals.

The depth to which a cast metal has been distorted by cold working, for example, in machining operations, can often be detected by making use of the fact that upon heating, recrystallization of the cold-worked metal will occur.

Effects of Structure Upon Properties

The ultimate aim of any metallographic examination is to show in what manner and to what extent the characteristics of the material, particularly

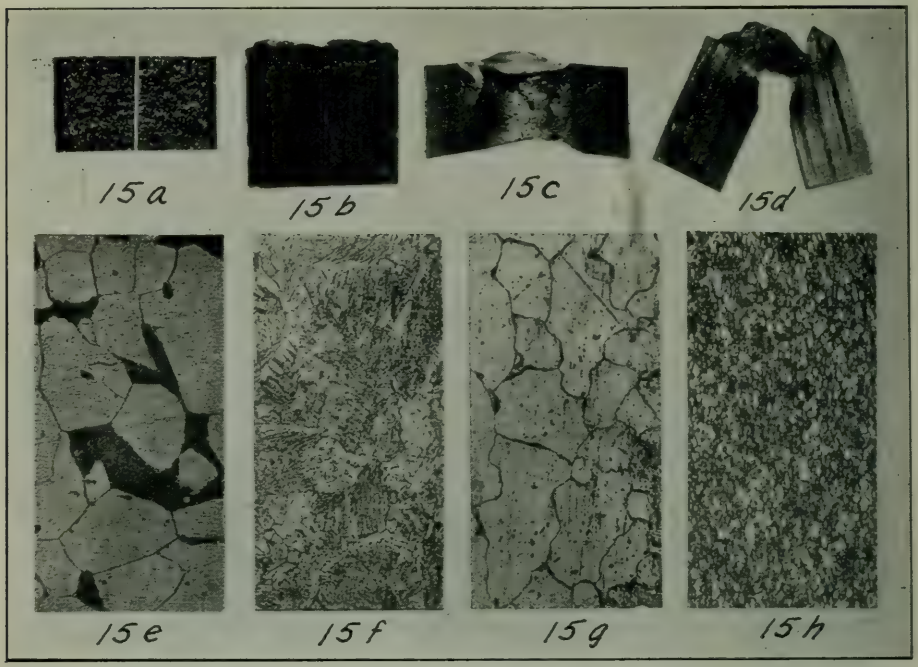


Figs. 14a-14c—Microstructure of copper-lead alloys and appearance of specimens of the same after testing in compression. Fig. 14a—Alloy of approximate composition; copper, 77 per cent; lead, 23 per cent. × 100. Fig. 14b—Alloy of approximate composition; copper, 60 per cent; lead, 40 per cent. × 100. The black network indicates the spaces in the copper "sponge" initially filled with globules of lead, traces of which still remain in place after the polishing of the sample. The specimens were slightly etched with concentrated nitric acid. Fig. 14c—Compression specimen of alloy Fig 14b, after test. × 1. The specimen sheared when compressed sufficiently, in a manner similar to "brittle" alloys.

the mechanical properties, are dependent upon the particular features characterizing the structure of the metal under observation. To discuss this phase of the subject, in this paper, even in a manner only approximately complete, is manifestly impossible. Only a few of the most obvious effects of structure upon the properties will be mentioned.

Hard and Soft Constituents

Many of the alloys most useful from the industrial standpoint, consist of two or more constituents which vary very widely in their characteristics. One is often relatively soft and ductile, while a second is hard and brittle. Such a condition occurs in steels, in aluminum casting alloys, and in bronzes, particularly those for bearing purposes. The softer constituents gives the required ductility, while stiffness and strength are contributed by the harder one which is disseminated throughout the soft matrix.



Figs. 15a-15h—Appearance of specimens of low-carbon steel with different thermal treatments showing the relation of impact properties to the microstructure of the material. Figs. 15a-15b—Fractured face and side-view of specimen of low-carbon steel broken by the Fremont impact test of a falling weight. × 1½. Figs. 15c-15d—Fractured face, and side view of a second specimen of the same material tested in the same way. × 1½. Fig. 15e—Microstructure of specimen of Figs. 15a-15b, × 100. The steel has been rendered coarsely-grained evidently by overheating in the annealing process. Fig. 15f—Microstructure of specimen Figs. 15c-15d. × 100. Etching reagent, 2 per cent alcoholic solution of nitric acid. Fig. 15g—Microstructure of soft iron wire (very low carbon steel) which was as "brittle as glass" when an attempt was made to bend it at the temperaure of liquid air. × 100. Fig. 15h—Microstructure of a wire of similar composition which proved to be very tough at the temperature of liquid air and withstood several complete bends, 180 degrees, before breaking. × 100. Note the difference in grain size of the brittle material, Fig. 15e and Fig. 15g, as compared with similar metal in the tough condition, Fig. 15f and Fig. 15h.

Fig. 13 shows a specimen of cast zinc-bronze which was stressed in tension until fracture occurred. The soft ductile copper-rich matrix easily adapted itself to the applied loading, the hard brittle tin-rich constituent was shattered and broken, as shown, when stressed sufficiently. The examination of a test specimen of an aluminum casting alloy broken in tension often is very enlightening concerning the results of the test. The hard constituent of the alloy consisting of a compound of aluminum and copper ($Cu\ Al_2$), is often sufficient in amount to form a continuous network throughout the alloy. The course or path of the fracture of the test specimen is determined by this network, thus the results of a tension test of such a material depend primarily upon the amount and the properties of this constituent.

Soft Ductile Constituents

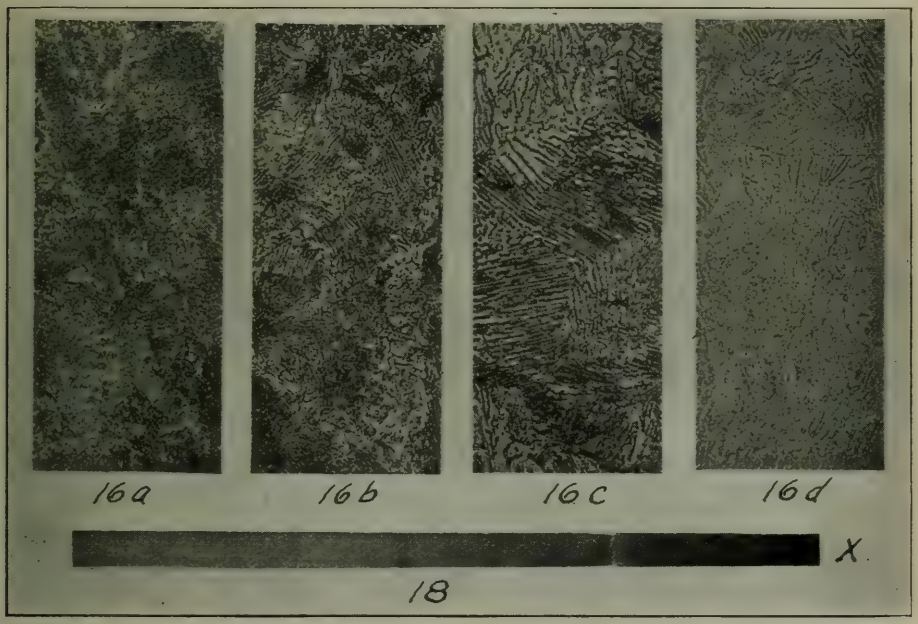
Copper and lead do not alloy with each other in the sense that most metals do. The ALLOY of these metals may be considered, for convenience, as a copper sponge, the interstices of which are filled with globules of lead, as is shown in Fig. 14.

Although both copper and lead, when reasonably pure, are highly ductile, the mixture of the two behaves in a rather anomalous manner when tested.

The behavior of the material when stressed in tension is somewhat as might be expected. It is somewhat ductile but is decidedly inferior to metallic copper in its properties. The continuity of the copper matrix is so broken up and weakened by the enclosed globules of lead that the resulting tensile properties are correspondingly lowered. Although each of the two constituents is decidedly ductile under compression, the mixture of the two behaves in a manner characteristic of a brittle material. Instead of flattening to any appreciable extent the specimen shears in a manner such as is expected, for example, in cast iron. The enclosed globules of the lead undoubtedly contribute largely to the failure of the specimen in the manner shown by their action as a LUBRICANT. The ultimate strength in compression of lead is very much lower than that of copper, thus the lead yields under the applied loading and FLOWS long before the copper is stressed to a degree which would cause appreciable deformation.

Orientation of Test Specimen With Respect of Material Tested

A worked metal has a more or less FIBROUS structure depending largely upon variations in composition across a section of the ingot used and particularly upon the various inclusions within the metal. It is evident that the mechanical properties, when measured ACROSS a laminated or fibrous material will be quite different from those of the same material, the test specimen of which was cut PARALLEL to the course of the fibres. In the latter



Figs. 16a-16d—Microstructure of eutectoid carbon steel (0.85 per cent carbon) showing the effect of rate of cooling upon the physical state of the pearlite. × 500. The specimens were heated to 800 degrees Cent. and cooled as follows: Fig. 16a, cooled in air; the material consists largely of sorbite. Fig. 16b, cooled in lime; the material contains patches of fine lamellar pearlite and some sorbite. Fig. 16c, cooled in furnace; coarse lamellar pearlite with some spheroidizing of the pearlite has resulted. Fig. 16d, cooled in furnace at a much slower rate than in Fig. 16c, the pearlite has been largely spheroidized or "divorced." Etching reagent, 5 per cent alcoholic solution of picric acid. Fig. 18—Apearance of a 1 per cent steel rod hardened, differentially tempered, and then immersed in dilute sulphuric acid. × 1. The hardened rod was differentially tempered by heating the end x, the other one being kept cold by water.

case which covers by far the greater majority of the test specimens used in industrial testing, the mechanical properties are not seriously affected. A striking illustration of the effect of the orientation of the test specimen to mechanical properties is shown in Table I.

Table I

Tensile Properties of "Flaky Steel" as Revealed by Transverse and by Longitudinal Test Specimens.

Specimen No.	Proportional limit lb. sq. in.	Yield Point lb. sq. in.	Ultimate Strength lb. sq. in.	Reduction of area per cent	Elongation in 2 in. pc.	Modulus of Elasticity lb. sq. in.
T	53,500	56,100	59,200	1.5	1.5	29,000,000
Tl	65,000	67,000	92,950	5.0	3.5	29,000,000
L	62,500	65,000	106,500	52.0	26.5	29,500,000
Ll	62,500	65,000	106,850	50.5	26.0	29,300,000

When such material is subjected to some of the dynamic methods of testing, impact, fatigue, etc., the difference in the results obtained for the transverse specimen as compared with those for the longitudinal specimen, is usually even more marked than those of the tension test.

Coarsely Grained Metals

Coarsely grained metals are quite universally regarded with disfavor although there often appears to be no evidence at hand to demonstrate the unsuitability of such material for many purposes. The brittleness, usually attributed to large grain size is not very well revealed by a tension test, at least as ordinarily carried out. A shock or impact test reveals the effect of coarse grain upon mechanical properties in a much more striking manner, (Fig. 15).

Physical State of Microscopic Constituents

Considerable investigative work has been done to show how the mechanical properties of carbon steels, particularly those of eutectoid composition, vary with the physical state of the pearlite, the steel being in the softened state throughout and the pearlite ranging from the lamellar type through various stages to the completely DIVORCED or SPHEROIDIZED condition.

The influence of the physical state of the pearlite in steel upon the properties is well shown by a study of the magnetic characteristics of the same steel after various treatments. The specimens of the steel of Fig. 16 were cooled from the same tempereature (800 degrees Cent.) at rates so chosen that the structure of the different specimens varied from a fine sorbitic condition to a divorced or spheroidized pearlite. The magnetic properties of the corresponding specimens are given graphically in Fig. 17. Without discussing here the significance of the various properties revealed by the magnetic tests it will be evident that the properties of the steel are affected to a marked degree by the changes which have been brought about in the physical state of the pearlite. Corresponding differences in the mechanical properties also would be found upon testing although perhaps of not so great a magnitude as in the magnetic properties since the magnetic tests are much more sensitive than the ordinary mechanical ones and often reveal changes which are detectable by almost no other means.

Chemical Properties

The chemical property of metals and alloys which is probably most important industrially, is that designated by the rather loose term of *solubility*. Upon this property depends the etching of metallographic specimens, the coloring of metallic surfaces, the corrodibility of materials under service conditions, and often, by the selective corrosion of certain constituents, the complete deterioration of the entire alloy in service. This property of an alloy is often influenced to a marked degree by the structure and the following examples are cited as typical of this effect of structure upon properties.

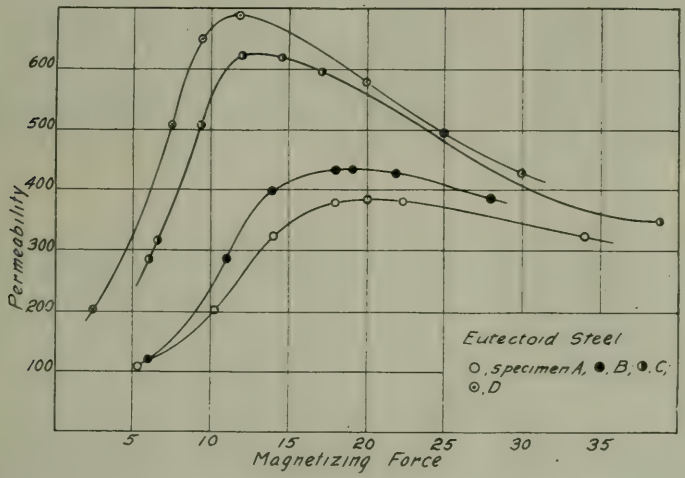


Fig. 17—Magnetic properties (permeability $\frac{B}{H}$ versus magnetizing force H) of eutectoid carbon steel after different annealing treatments.

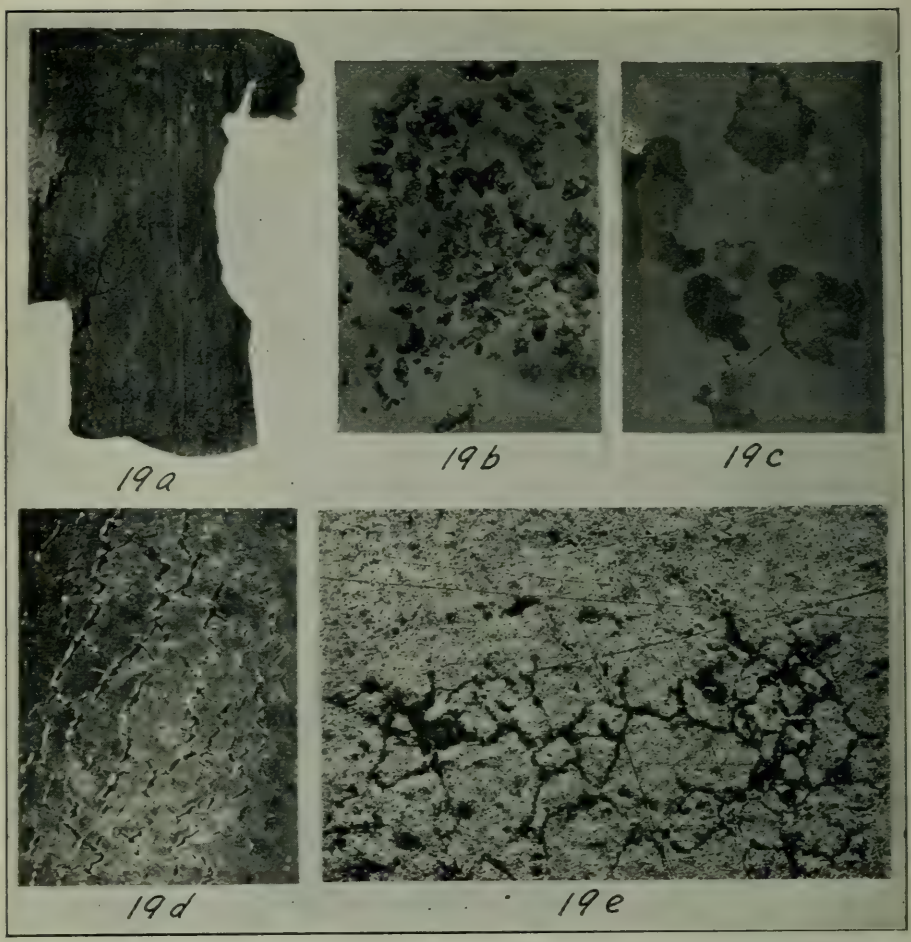
Solubility of Tempered Steels

It is quite well recognized that the solubility of steel varies considerably according to the heat treatment which it has received. To illustrate this, a rod of high carbon steel (approximately 1 per cent carbon) was hardened by quenching in water from a temperature of 765 degrees Cent. The hardened rod was differently tempered by heating one end to approximately 850 degrees Cent. while the other was kept cool with water. Thus the rod represented at different points along its length, tempering to all temperatures between the two extremes. When immersed in dilute sulphuric acid (20 per cent solution) for 17 hours the appearance shown in Fig. 18 was produced. The material in one of the intermediate stages of tempering is the most readily soluble, rather than the very hard or the very soft portions.

Considerable attention has been given to this property of tempered steels by foreign metallurgists and it has been shown, that the rate of solubility can be used as an index of the tempering a specimen of steel has received. Maximum solubility corresponds to a tempering at 400 degrees Cent. A special name, Osmondite, has been given to steel in this particular condition on account of its characteristic properties.

Corrosion

Only a brief mention will be made here of how structural features aid



Figs. 19a-19e—Appearance of lead after accelerated corrosion and of commercial lead which corroded in service. Fig. 19d—Surface appearance of a sheet of high grade lead (99.99 per cent) after immersion of 24 days in a solution of lead acetate (N) and nitric acid (0.08N) and bent at a slight angle. An intercrystalline brittleness resulted from the corrosive attack. × 5. Fig. 19b—Crystals which were detached from a sheet of commercial lead (lead, 99.72 per cent; antimony, 0.07 per cent; iron, 0.02 per cent; tin, 0.14 per cent) immersed for four days in an acidified solution of lead acetate. (400 grams lead acetate, 100 cubic centimeters nitric acid, 1000 cubic centimeters water). × 8. The corrosioin of the lead was intercrystalline in nature. Fig. 19c—Some of the crystals of Fig. 19b flatteneded out, × 8. Each crystal retained the characteristic malleability of lead, although the sheet as a whole was brittle. Fig. 19a—Appearance of a lead cable sheathing which corroded in service, approximate composition, tin 1.09 per cent, lead 98.3 per cent. × 1½. Fig. 19e—Cross-section of specimen Fig. 19a unetched. The lower edge of the micrograph coincided with the outer surface of the sheath. The corrosive attack of the metal was intercrystalline in its nature. × 50.

in the process of corrosion. In general the corrosive attack on a metal is more pronounced in the direction of the fibers than across them. This is most marked in case of accelerated corrosion by exposure to sea air, sea water or similar conditions. This may be attributed largely to the mechanical effect of inclusion streaks which afford lodgement for moisture so that the attack at such points is accelerated and to the difference in the electrochemical properties of streaks of the metal in various stages of cold-working. Brass containing approximately 60 per cent copper and 40 per cent zinc often used near

sea water or similar exposures exemplifies well the specific effect of a metallographic constituent upon the corrosion of a metallic material. Such a brass has a duplex structure; one constituent, the A being much richer in copper than is the second or β. The difference in the electrochemical potential of the two, A and β contribute to bring about difference in the resistance of the two to the action of sea water. The zinc from the β is leached out and a spongy mass of copper remains filling the spaces previously occupied by the β. Thus a weak brittle mass consisting of a sponge-like skeleton of the more or less unattacked A constituent and the pulverulent material resulting from the disintegration of the β, results.

A soft ductile metal like lead may under some conditions of accelerated corrosion become so brittle that it can be crumbled to powder in the fingers. This is most apt to occur if the lead is somewhat impure. Fig. 19 shows a section of a lead cable sheath which by electrolytic corrosion became so brittle that it could be reduced to a granular powder. Each grain, however, retained its initial ductility and the other characteristic properties of lead. The corrosive attack of the metal was essentially intercrystalline in character which was due largely in all probability to the impurity contained by the metal (1.09 per cent tin).

Applications of the Microscopy of Metals

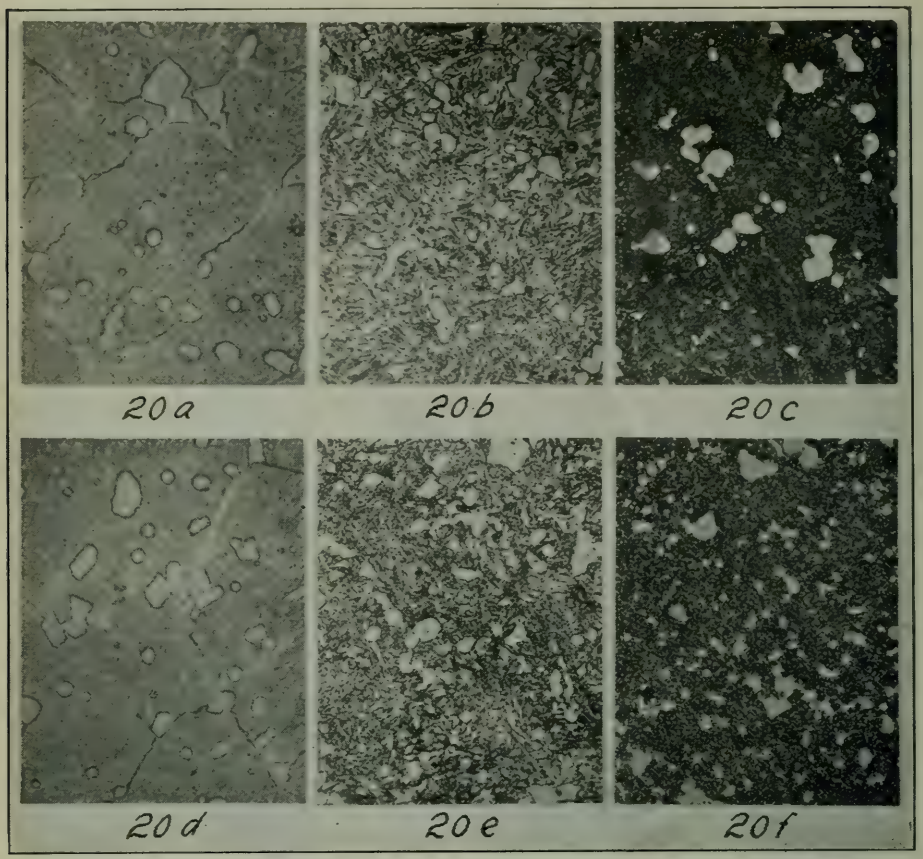
The most important industrial application of the microscopy of metals is undoubtedly its use in connection with the heat treatment of steels. Not only is it used for the routine method of examination of heat-treated stock to make certain that the prescribed treatment has been carried out and to show wherein lies the fault when the material after treatment does not show the expected mechanical properties but it is of inestimable service in specifying a proper heat treatment for new types of steels. A second important application of the method is to supplement chemical analysis. The description of the various applications can best be given by means of short references to a few typical cases rather than by a longer and more general discussion. Obviously, the discussion must be more or less fragmentary in character.

Relation of Microscopy to Heat Treatment

The question of grain size, grain refinement, etc. has already been referred to.

A knowledge of the microstructure is very helpful in explaining the peculiar characteristic properties of high-speed tool steels (Fig. 20) in order to specify properly the necessary heat treatment. When quenched from a sufficiently high temperature the material is, at least partially, austenitic in structure. Upon tempering at a relatively low temperature, it is converted into the martensitic state with an accompanying gain in hardness, usually termed *secondary* hardness. The martensitic state is changed into the troostitic condition only very slowly so that the material passes no further than the troostitic state upon tempering at a relatively high temperature. Hence this state together with the accompanying cutting properties (toughness and hardness) is retained by the material at the high temperature which prevails in the use of such tools.

Fig. 21 shows the structures which may be obtained by hardening a hypoeutectoid steel (carbon 0.46 per cent) by quenching from different temperatures. When a temperature only slightly above the transformation is used, considerable ferrite exists intermixed with the martensite and the material

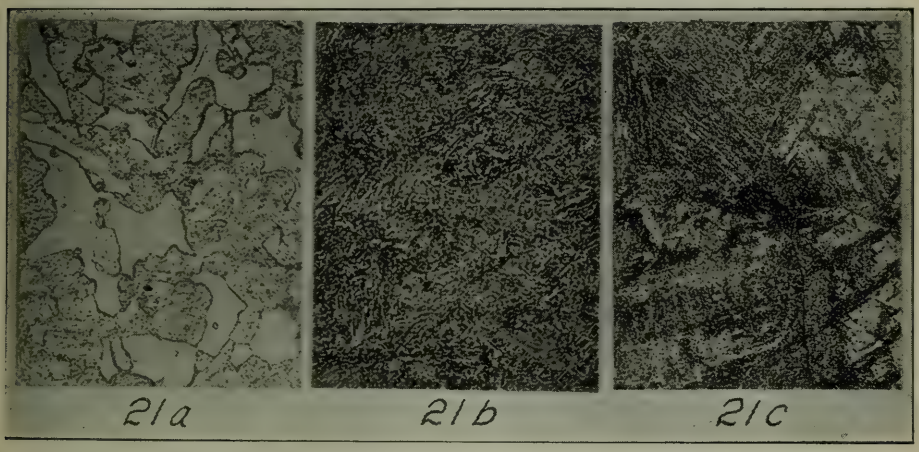


Figs. 20a-20f—Microstructure of high-speed tool steel illustrating the effect upon structure of tempering the hardened steel at different temperatures. × 500. The micrographs show the structure of a steel containing 0.77 per cent carbon; 17.8 per cent tungsten; 3.5 per cent chromium; 0.74 per cent vanadium after the treatments given below:—Fig. 20a—Quenched in oil from 1290 degrees Cent. A polyhedral structure resulted from this treatment and the material was rendered largely austenitic in its properties. Fig. 20d—Specimen Fig. 20 a, tempered 30 minutes at 200 degrees Cent. The crystals show interior markings suggestive of the beginning of the change into the martensitic condition. Fig. 20b—Specimen Fig. 20 d, tempered 30 minutes at 400 degrees Cent., the martensitic pattern has been fully developed. Fig. 20e—Specimen Fig. 20b, tempered 30 minutes at 600 degrees Cent.; although in the troostitic state, the martensitic pattern is still evident. Fig. 20c—Specimen Fig. 20e, tempered 30 minutes at 700 degrees Cent. Tiny globules of carbide precipitated from the previously existing solid solution by the process of tempering have begun to appear. Fig. 20f—Specimen Fig. 20c, tempered 30 minutes at 800 degrees Cent. The particles of carbide are more plainly visible than in Fig. 20c and the material is approaching the annealed state. Etching reagent, 2 per cent alcoholic nitric acid.

has not been fully hardened. Statements from as noted a source as the International Association for Testing Materials suggest that sorbite should be obtained by such a treatment. When quenched from above the A_{2-3} transformation temperature, no ferrite remains and a fine martensitic structure results. If a still higher temperature is used the martensitic structure becomes very coarse and intercrystalline cracks often form upon quenching.

Undesirable properties of steel are sometimes attributed to faulty heat-treatment used for the material, a microscopic examination of which shows that the cause is an entirely different one. A section of a forging of nickel steel intended for rifle parts was submitted for examination. Difficulties

had been encountered in drilling and the attempt had been made to overcome these by various annealings of the material. The microscopic examination of the annealed piece revealed a martensitic core while the outer portions were of the usual ferrite-pearlite structure (Fig. 22). Subsequent chemical analysis showed that the nickel content of the central portion was very much higher than that of the outer parts, enough so as to render the material martensitic even upon slow cooling. Evidently heat treatment could not be expected to



Figs. 21a-21c—Microstructure of medium carbon steel after different hardening treatments. Fig. 21a—Specimen of 0.46 per cent carbon steel quenched in water after heating 15 minutes at 750 degrees Cent. (1380 degrees Fahr.), just above the A_1 transformation. The structure consists of ferrite and martensite, × 500. Fig. 21b—Specimen similar to Fig. 21a, quenched in water after heating 15 minutes at 850 degrees Cent. (1515 degrees Fahr.), just above the A_3 transformation. The structure consists entirely of very fine martensite, × 500. Fig. 21c—Specimen similar to Fig. 21a, quenched in water after heating 15 minutes at 1200 degrees Cent. (2190 degrees Fahr.). A very coarsely-grained martensitic structure has resulted in which intercrystalline quenching cracks are abundant. × 100. Etching reagent, a 2 per cent alcoholic solution of nitric acid.

improve the machining properties of such material, the remedy had to be sought in the melting practice used in the production of the steel.

An interesting example of the effect of furnace atmosphere is the defect which may result in copper which has been improperly annealed. The metal may be rendered brittle and useless by numerous fine intercrystalline cracks throughout the interior. This is to be attributed to the action of the atmosphere in which it was heated rather than to the temperature used. The particles of cuprous oxide, which are always present to some extent in remelted copper, are reduced by hydrogen or other reducing gases which readily penetrate the heated metal. The pressure of the gaseous products resulting from their action upon the oxide is sufficient to produce the internal cracks throughout the hot metal.

Supplement to Chemical Analysis

The advantage which may be taken of a macroscopic examination in the proper sampling of a segregated steel for chemical analysis has already been referred to. Such an examination is also particularly valuable for some of the white metal alloys which are subject to *liquidation* during solidification on account of the difference in density of the various constituents, as is illustrated by lead-antimony alloys.

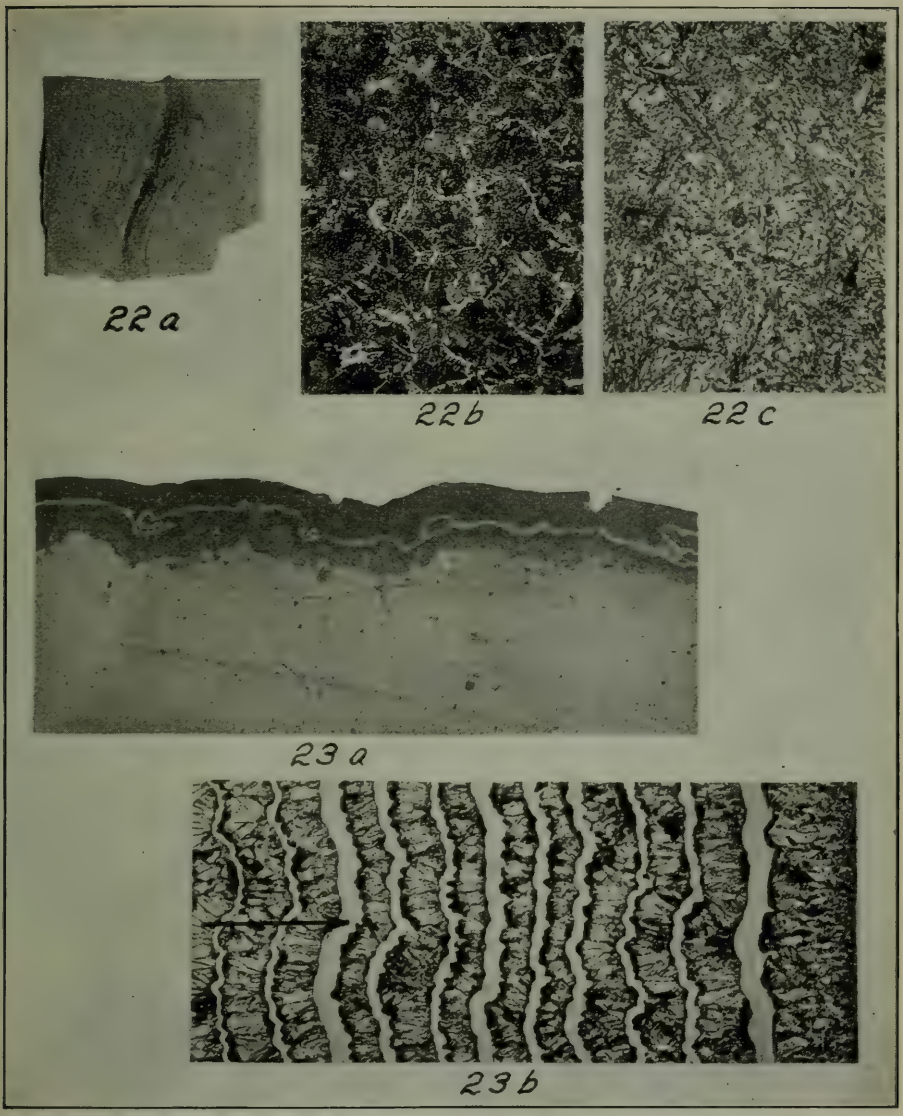
The microscopic method is of decided value in supplementing the chemical study of the various metallic coatings used for protective purposes particularly on iron and steels. The brass coating shown in Fig. 23 in reality consists of three layers, one of nickel and two of brass. It is evident that with this information in mind, the chemical determination of this coating can be carried out and interpreted in a much more logical way than without it. The duplex structure of electrolytic deposit of alternate layers of copper and nickel now being used with success to replace steel plates in engraving work is shown also in Fig. 23. The miscroscopic method may be used also in determining the thickness and distribution of the coating material. Although laborious, this method is often the only one available for such determinations.

Because of the relatively higher price for wrought iron as compared to mild steel there is at times a tendency to *adulterate* this product with additions of the cheaper metal. While the chemical analysis will indicate in a general way that such additions have been made, the metallographic method is almost indispensable for quickly revealing the extent of such contaminations. Fig. 24 shows the appearance of a specimen of commercial wrought iron which has been suitably prepared to show the results produced by the addition of low carbon steel to material of this kind.

Considerable importance is attached to the study of the occurrence of gases in metals, and in particular those gases which are given off by steel when heated in vacuo. Among the principal gases obtained in this manner is carbon monoxide. A study of the microstructure of specimens of steel after being heated in vacuo shows that a very appreciable decarburization occurs in such material, a fact which throws considerable light on the origin of at least some of the evolved gases. The carbon is often removed for a considerable depth at the surface of a specimen by heating in vacuo, and evidently a chemical reaction, the reverse of that by which carburization of steel in the cementation or case hardening process is brought about, occurs during the heating, giving rise to carbon monoxide as one of the products.

The chemical determination of slag in steel is at its best rather unsatisfactory. Even if good checks are obtained in duplicate determination, the interpretation of the results is a matter of considerable difficulty. That this must be so is evident upon an examination of the microstructure of a slag thread from wrought iron. The duplex nature of this simple slag may be plainly shown and it may be inferred that in the case of the complex steels, in the manufacture of which the additions to the metal are often several in number and varied in composition, the resulting slag must be correspondingly complex in its nature.

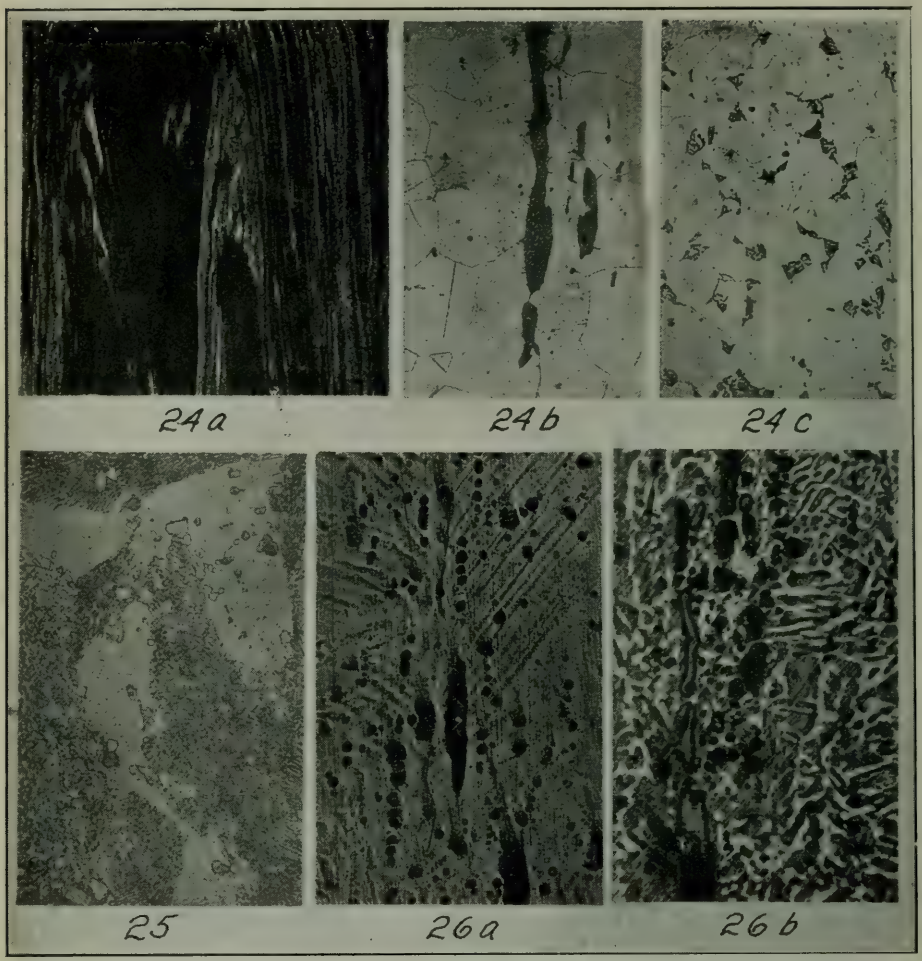
The microscope is often an indispensable means for determining the role played by certain additions made to alloys in the course of the preparation. This is true particularly for steels. Thus an examination of the structure of titanium-treated steels shows that this element, titanium, in the quantities usually added to steel does not alloy with the metal in the sense that many added elements do. Its role is to free the metal of undesirable substances present and then leave the metal in the slag, carrying the detrimental substance combined with it. It appears to be especially active in combining with nitrogen. Zirconium appears to act in a manner similar to that of titanium when added to steel in small amounts, in that it frees the metal from some undesirable substance (not necessarily nitrogen) and then escapes from the metal in some combined form in the slag. The inclusions which are found in zirconium-treated steel are of a very characteristic shape and yellow color (Fig. 25). On the other hand, the primary role of many other added elements



Figs. 22a-22c—Structure of a defective nickel steel forging caused by improper melting practice. Fig. 22a—Macrostructure of a longitudinal section, deeply etched with concentrated hydrochloric acid, showing the core due to the nondiffusion of nickel in the molten steel. × 1. Fig. 22b—Microstructure of specimen Fig. 22a, as received from the mill, outside the core. × 100. Fig. 22c—Microstructure of the core of specimen Fig. 22a, as received from the mill. The nickel content of this part was so high that it remained martensitic even upon slow cooling. × 500. Etching reagent, Fig. 22b and 22c, 2 per cent alcoholic solution of nitric acid. Figs. 23a-23b—Microstructure of complex metallic coatings produced by electrolytic deposition. Fig. 23a—Cross-section of a "brass" coating used on a steel base; the coating consists of three layers, the intermediate one being of nickel, × 500. Fig. 23b—Cross section of an electrolytic deposit consisting of alternate layers of nickel (light) and copper (crystalline), the metal being deposited in the direction shown by the arrow. × 100. Etching reagent, ammonium hydroxide and hydrogen peroxide.

is to react with the steel and to modify the properties, either of the ferrite as in the case of nickel, or the carbide as in the case of chromium.

The form in which certain elements occur in steel and their distribu-



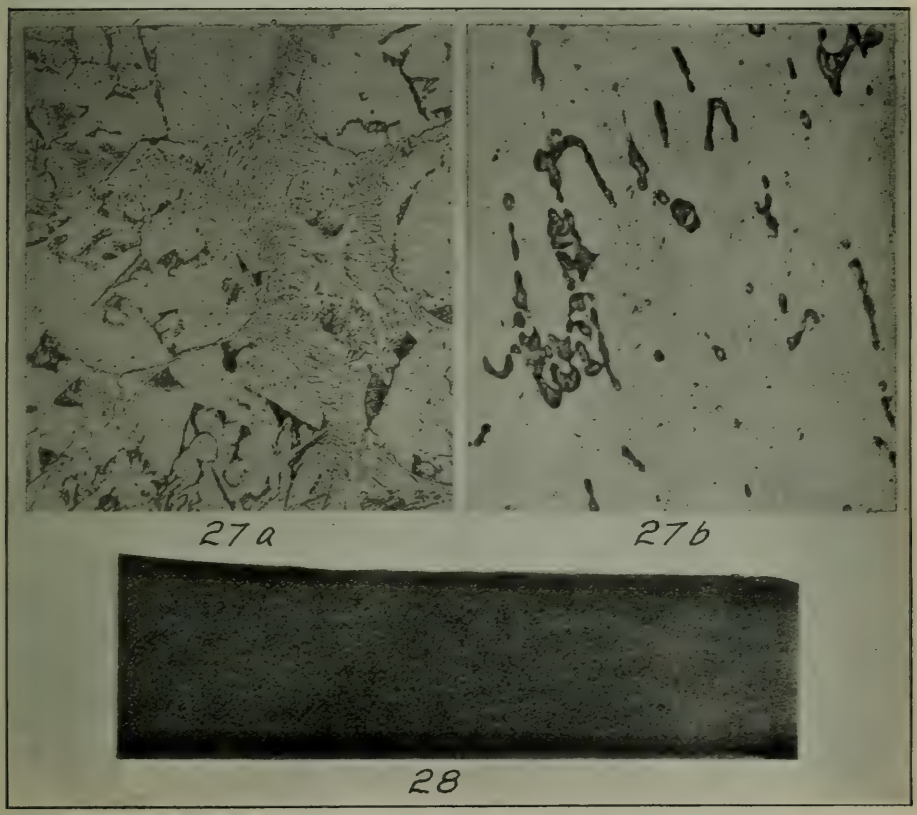
Figs. 24a-24c—Structure of wrought iron to which additions of steel have been made. Fig. 24a—Macrostructure of a longitudinal section of a 2-inch round bar of wrought iron, deeply etched with hot concentrated hydrochloric acid. × 1. The white streaks represent the additions of steel. Fig. 24b—Microstructure of the metal of the dark portions of Fig. 24a. This has the characteristic structure of wrought iron. × 100. Fig. 24c—Microstructure of the metal of one of the light streaks of Fig. 24a. The metal is low-carbon steel. × 100. Etching reagent, 2 per cent alcoholic solution of nitric acid. Fig. 25—Microstructure of steel to which additions of zirconium have been made. × 500. The small light-colored inclusions, square or triangular in outline, are characteristic of steel to which zirconium has been added. They are of a striking lemon-yellow color. Etching reagent, 2 per cent alcoholic solution of nitric acid. Figs. 26a-26b—Microstructure of wrought iron of high phosphorus content, showing the lack of uniform distribution of this element even within the individual crystals. × 100. 26a—Longitudinal section of wrought iron, high in phosphorus (0.36 per cent) annealed at 600 degrees Cent. The phosphorus banding within the individual grains has persisted after this treatment; etching reagent, 10 per cent alcoholic solution of nitric acid. 26b—Longitudinal section of high phosphorus wrought iron, etched with acidified solution of cupric chloride. (Stead's reagent.)

tion throughout the metal are often of much more importance, as far as the properties of the metal are concerned, than the precentage of the element present. This has already been mentioned in the case of sulphur. Phosphorus in the amount usually present in iron and steel, exists in solid solution in the ferrite. The distribution is often far from uniform throughout the metal, and even within the individual crystals the distribution may be far from uniform as is shown in Fig. 26.

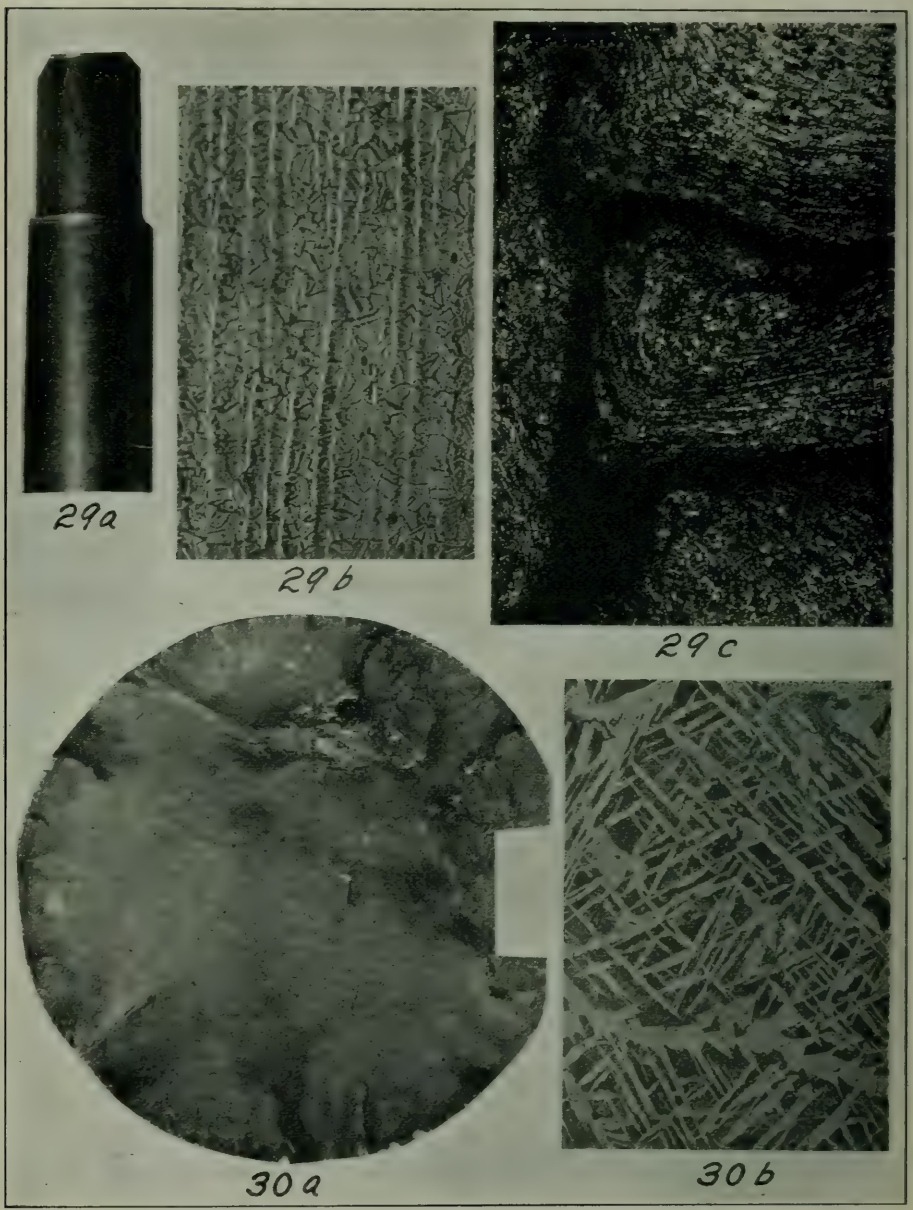
Control of Metallurgical Operations and Products

A knowledge of the structure of an alloy, particularly a new one, will often aid materially in carrying out the mechanical working of the material satisfactorily. Fig. 27 shows the structure of a boron steel. When the attempt was made to roll this steel under the same conditions used with satisfactory results for steels of similar composition but containing no boron, the metal crumbled and cracked badly in the rolls. Indeed, some ingots were so brittle that they broke under their own weight when carried from the furnace to the rolls. By heating the ingots for a sufficiently long time until considerable coalescence of the eutectic occurred and by reducing the temperature of the ingot somewhat, that is, below the eutectic temperature, no unusual difficulties on working the metal were encountered.

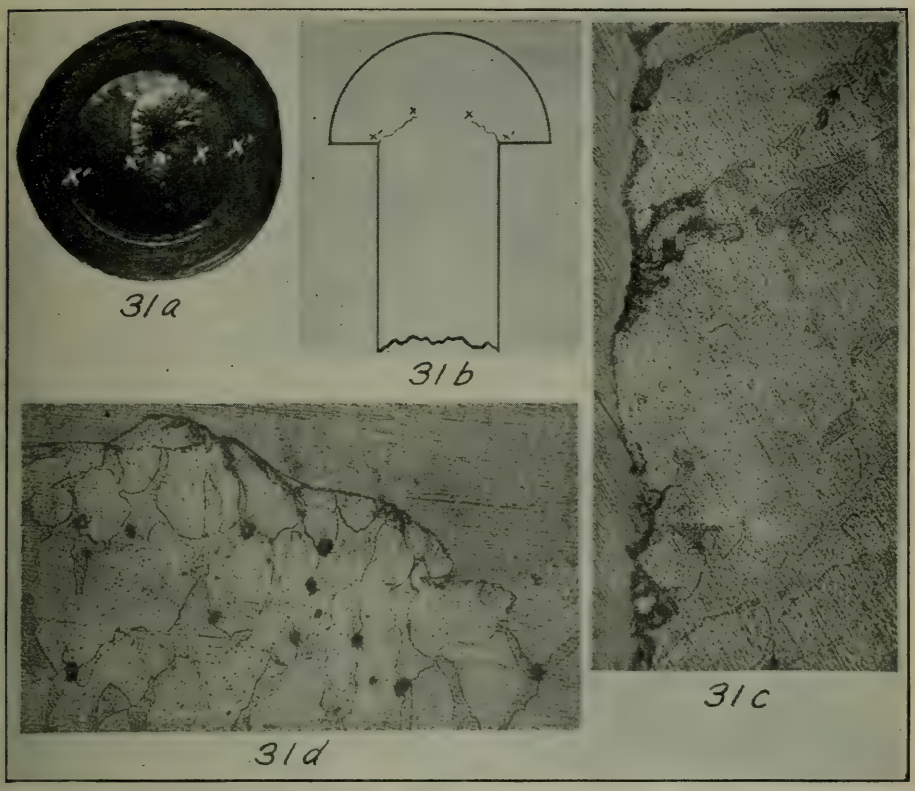
The microscope is often valuable in determining the nature of certain metallurgical products masquerading under misleading names. Thus for example, the nature of wrought iron can be established with certainty by this



Figs. 27a-27b—Microstructure of low-carbon steels to which additions of boron have been made. × 500. Fig. 27a—Section of an ingot of boron steel (carbon 0.16 per cent, boron 0.49 per cent) which broke in the rolls and could not be worked. The addition of the boron causes the formation of the eutectic shown; etching reagent, 2 per cent alcoholic solution of nitric acid. Fig. 27b—Longitudinal section of a rolled plate of boron steel (carbon 0.16 per cent, boron 0.39 per cent) showing the coalescence of the eutectoid which has occurred. Etching reagent, hot alkaline solution of sodium picrate. This reagent colors the carbide a dark brown and sometimes nearly black. Fig. 28—Macrostructure of a steel block showing surface changes caused by cutting the steel by means of the acetylene flame. × 1. The surface has been appreciably hardened for a considerable depth by the chilling action of the cool metal of the interior upon the hot metal of the surface after the flame was withdrawn; etching reagent, aqueous solution of ammonium persulphate.



Figs. 29a-29c—Structure of monel metal showing interior defects originating before the metal was rolled. Fig. 29a—Monel metal rod showing an internal flaw. × 1. Fig. 29b—Longitudinal section of sound monel metal showing "work lines." × 100. Fig. 29c—Section through the defect in specimen Fig. 29a. The distortion of the "work lines" in the neighborhood of the defect proves that the defect existed in the metal previous to the rolling of it. × 50. Etching reagent, Figs. 29b and 29c, concentrated nitric acid. Figs. 30a and 30b—Structure of a steel shafting which failed in service by fatigue. Fig. 30a—Face of the fracture, which originated in a key-way, × ¼. Fig. 30b—Microstructure of the metal of the interior. × 50. Evidently the forging received no treatment for grain refinement; etching reagent 2 per cent alcoholic solution of nitric acid.

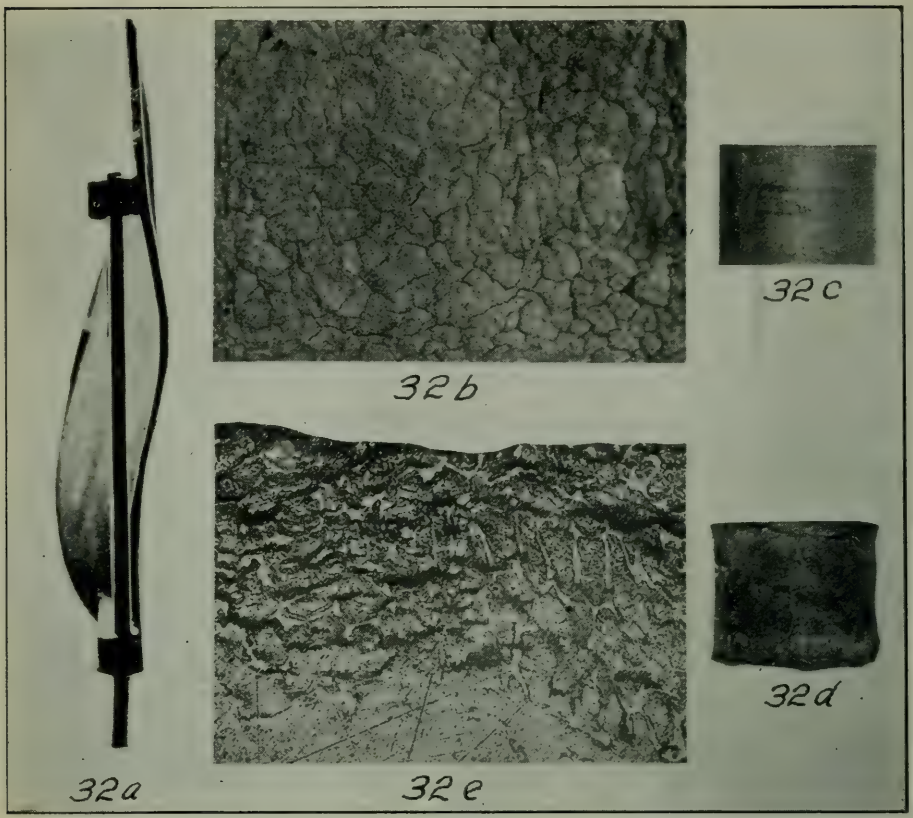


Figs. 31a-31d—Structure of a brass (muntz metal) bolt which failed in service, evidently by being corroded while stressed in tension. Fig. 31a—Fractured face of the bolt-head which dropped off "of its own accord." × 1. Fig. 31b—Sketch of longitudinal section of the bolt just before the head was detached. Fig. 31c—Microstructure of the metal at the fracture in the portion x—x' of Fig. 31a and 31b. The beta constituent has been dezincified by the corrosive action of sea water to a considerable depth (black in micrograph) by corrosion. × 250. Fig. 31d—Microstructure of the metal at the fracture in the central portion, x—x in Figs. 31a and 31b. No corrosion has occurred here, tensile stress alone caused the fracture of the part. × 250. Etching reagent, ammonium hydroxide.

means; semisteel can be shown to be only a particular grade of cast iron, having none of the characteristic properties of steel. An interesting example which may be cited is that of a specially prepared copper advertised and sold as a deoxidizer for copper and other alloys. The examination of the material showed that the deoxidizer itself, contained very appreciable amounts of cuprous oxide. "The special treatment" given the material to render it a deoxidizer was not sufficient to prevent oxidation of the metal itself from occurring during the process of treatment. It is difficult to see how such a substance then would have much effect as a deoxidizer when added to other metals.

Certain metallurgical processes are most readily and surely controlled by means of examinations of the structure of the product at various stages of the process. The manufacture of malleable iron offers a good example of this as well as the converse of this, the cementation process.

Fig. 28 shows a block of steel which has been cut by the oxyacetylene flame. The surface change in the metal, which at first sight might be mistaken for a carburized layer, is due to the "quenching" action of the cold



Figs. 32a and 31e—Appearance of certain aluminum alloys of high zinc content after deterioration. Fig. 32a—Fuse box cover, approximate composition; aluminum, 15 per cent; lead, 0.4 per cent; zinc remainder, which was used in a tropical climate and warped in service. × ¼. Fig. 32b—Surface of specimen, showing "alligator cracks." × 1. Fig. 32c—Cylinder of an alloy, composition: copper, 1.4 per cent; aluminum, 15.2 per cent; zinc, 83.4 per cent, exposed to "dry heat" (100 degrees Cent.) for six days. The dimensions of the specimen remained unchanged. × 1½. Fig. 32d—Specimen similar to Fig. 32c exposed to "moist heat" 100 degrees Cent., for six days. The specimen expanded and cracked. × 1½. Fig. 32e—Cross-section of specimen similar to Fig. 32d, showing the "expansion cracks" which formed in the metal near the surface by the action of heat and moisture; most of these occur in the eutectic; the specimen was unetched. × 100.

metal of the interior upon the hot metal at the surface after the removal of the flame. This special application of the action of a flame upon steel has been perfected, patented and successfully applied in the surface hardening of complex steel shapes, which would be distorted or would crack if hardened in the usual manner.

In the study of the mechanical working of metals it is often necessary to follow the material through the various stages through which it passes. In this connection the chemical nonhomogeneity of metal, for instance, phosphorus-banding as has been indicated previously serves a useful purpose, other structural features often answer the purposes in other alloys, thus, as is shown in Fig. 29, certain discontinuities within a wrought round bar of monel metal were clearly shown by the characteristic *work lines* to have had their origin while the metal was in a plastic state and not to have been produced by any treatment given the material subsequently by the user.

Failure of Metals in Service

In the investigation of the failure of metals which has occurred during service the microscope has proved a very valuable aid and the structure often reveals evidence which the ordinary methods of testing fail to detect entirely. To discuss the relation of the microstructure to the failure of metals is manifestly impossible here, brief references only to a few specific cases will be used as examples.

Fig. 30 shows the appearance of a fracture which occurred in service in a 10-inch steel shafting. The fracture had the characteristic appearance of a *detail* or *fatigue* break which started in the angle of a key-way. The examination of the structure showed that it was almost a perfect one for such a failure, for the particular composition of steel used. Evidently the material had received no annealing treatment whatever for grain refinement after the forging of the shaft was completed. The large crystals with their prominent Widmanstättian structure are almost perfect, so far as failure to withstand repeated or vibratory stresses is concerned.

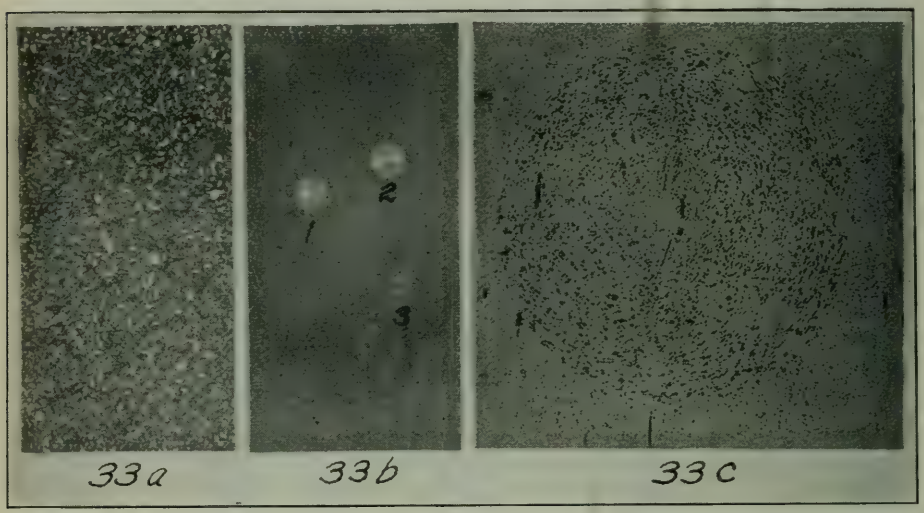
Fig. 31 shows the fractured face of a Muntz metal bolt head which dropped off in service "of its own accord." Examination of the microstructure showed that the failure was due to selective corrosion of the zinc-rich or β constituent was localized at the apex of the angle between the shank and head and accelerated by the service stress carried by the bolt. It can readily be shown that corrosion of such alloys at the apex of a narrow groove, is much more intense than elsewhere in the same material, when the specimen is subjected to a tensile stress while surrounded by the corroding agent, for example, sea water. This behavior is to be attributed to the fact that the stress carried is not distributed equally in all cross sections but is much higher at the bottom of the V-groove, than elsewhere. Under the combined action of corrosion due to sea water and the service tensile stress carried by the bolt, the portion of the fracture x—x′ was gradually produced, this has the appearance of a *detail* or *fatigue* break. When the cross-sectional area became small enough so as to break under the applied loading the central portion broke as a simple tensional break. The microstructure of the two portions confirms this; in the portion x—x′, the β constituent at the fractured edge of the material shows evidence of deterioration by dezincification while in the central portion the alloy is sound and unchanged up to the extreme edge of the fracture.

Service Deterioration of Alloys

It sometimes happens that an alloy used for some specific purpose deteriorates, usually in a chemical way, under the peculiar conditions to which it is exposed, although for other purposes and for other conditions the material is suitable in every respect. The material of Fig. 32 an alloy of aluminum and zinc was used in a tropical climate and hence was exposed to conditions of high humidity and temperature. The specimen shown, a fuse-box cover, originally flat, warped severely and bent out of shape. The surface showed characteristic "alligator cracks." Fig. 32c shows the appearance of two test specimens of a somewhat similar alloy intended for die castings after exposure to dry and to moist heat (100 degrees Cent.). Heat, in the absence of moisture, had no appreciable effect upon the material, the specimen retained its initial dimensions and shape. The sample exposed to the combined action of heat and moisture, however, rapidly deteriorated by permanent expansion and distortion of the piece. An appreciable increase of hardness also accompanied this change. Microscopic examination showed

that the eutectic was the portion attacked. Presumably oxidation takes place with accompanying increase of volume, the presence of moisture being necessary for this change to occur.

A somewhat similar change sometimes occurs in the filling used for fusible boiler plugs. The filling prescribed for such plugs is very high grade tin. The presence of impurities in small amounts, particularly zinc, has been found to stimulate the oxidation of the tin filling so that in time the plug filling may become a hard infusible mass of oxide. In this case, as the



Figs. 33a-33c—Appearance of the etched surface of a ball used in Brinell hardness determinations and the indentations produced. Fig. 33a—Etched surface of hardening steel ball (chromium steel) used in Brinell hardness determinations, etching reagent 1 per cent alcoholic nitric acid. The white particles are the globules of carbide and are unattacked by moderate etching. × 500. Fig. 33b—Brinell indentations produced on a polished specimen of file steel (carbon approximately 1.4 per cent). with a load of 1000 kilograms applied for 30 seconds on a 10 millimeter ball. Numbers 1 and 2 were obtained with an etched ball, No. 3 with a polished ball. The irregular spot at No. 3 is an ink mark for identification. × 3. Fig. 33c—Indentation No. 1 of Fig. 33b. × 50. The matt appearance of the indentations, Nos. 1 and 2, of Fig. 33b, is due to the great number of tiny pits produced by the carbide particles, which cover the face of the indentation. The indentation shows two distinct concentric zones, apparently due to a difference in the pressure transmitted to the steel plate being tested.

above, the eutectic is the constituent which is most rapidly attacked and oxidized under the combined action of heat and moisture. A very considerable increase in volume accompanies the change in the tin filling of such plugs.

The terminals in spark plugs are very often made of nickel wire, and severe deterioration sometimes occurs. These nickel terminals show more or less deterioration in all spark plugs on account of the high temperature and perhaps to other conditions accompanying their use. This deterioration consists of an intercrystalline attack which may in time develop into visible intercrystalline fissures or cracks. A study made of various types of spark plugs showed that in plugs of certain design the nickel terminals were subject to more or less tensional stress while hot, and in such cases the deterioration was very pronounced, very deeply penetrating cracks formed which soon completely severed the entire wire. It was shown by the microscopic examination of similar wires which had been subjected to the combined action of tensional stress and heat that the material deteriorated in a manner identical in appearance with that of the terminals of the spark plugs produced in service.

Miscellaneous

A knowledge of the microstructure of metals may also be useful in a great number of miscellaneous ways, only one of which, however, will be mentioned here, the application of microstructure in Brinell hardness determinations. Fig. 33 shows how advantage may be taken of the etching properties of the material of the steel ball used in the Brinell hardness test in order to obtain a higher degree of accuracy in the results obtained when testing hard materials. The impression of the ball upon the surface of a hard metal, particularly if the latter is polished, is very indefinite and the measuring of the diameter of the impression is a matter entailing considerable uncertainty. The ball used for the purpose consists practically always of a chromimum steel of such a composition that in the hardened state it contains free carbide in the form of numerous rounded particles. By etching the ball slightly before use (2 minutes' immersion in one per cent alcoholic nitric acid) the "flowed metal" on the polished surface can be removed and the hard carbide particles revealed. An impression made with such an etched ball upon a polished surface of a hardened steel is very much more conspicuous than one obtained with a polished one. When the high pressure is applied, the carbide particles produce a multitude of tiny pits over the surface of the indentation of the ball, thus giving a *matt-finish* to the indentation which aids very materially in defining its limits.

Many other cases might be cited of practical applications of the microscopy of metals. It is believed, however, that from what has been given it is quite evident that the metallurgical microscope is one of the most useful aids at one's disposal in the study and testing of metals.

NOTES FROM THE BUREAU OF STANDARDS

Apparatus for the Determination of the Magnetic Properties of Short Bars

THE growing interest among engineers and designers in the correlation of the magnetic and other physical properties of iron and steel has given impetus to the study and development of methods for making the necessary magnetic measurements. Many materials of an experimental composition or of extreme purity are available only in limited quantities, and the ability to obtain magnetic measurements on small samples would be of decided advantage both from the point of view of economy of material and because of the ease of the machining and heat treatment.

The direct determination of the magnetic properties of small samples with any degree of accuracy is a difficult matter, but the Bureau of Standards has recently developed an apparatus capable of measuring the magnetic properties of such a sample with a satisfactory degree of precision. The method involves the comparison of a sample of the material to be tested, which is in the form of a cylindrical bar 6 millimeters in diameter and 10 centimeters long, with a reference bar, the apparent magnetic properties of which have been determined through calibration by means of standard bars having accurately known properties. This method is capable of giving results accurate within 5 per cent for most materials. As the accuracy depends, to some extent, upon the degree with which the properties of the test bar agree with those of the standard bar used for the calibration. The range of materials which can be tested with satisfactory accuracy depends upon the range of the properties covered by the series of standard bars. This work will be found described in Scientific Paper No. 448 of the Bureau of Standards.

Effect of Temperature, Deformation, and Rate of Loading on the Tensile Properties of Low Carbon Steel Below the Thermal Critical Range

The metallurgical laboratories of the Bureau of Standards have been conducting tests on the properties of various grades of boiler plate through the range of 20 to 465 degrees Cent. This has been carried on to determine the effects of blue and cold work, variations in rate of loading, elastic overstrain, and subsequent behavior of the overstrained steel with time. The results of this work have been published in Technologic Paper No. 219.

The paper describes the special apparatus employed for making high temperature tensile tests and the differences in behavior of the steel which were noted in various temperature ranges. It was found that the proportional limit of the several grades of plates does not decrease with the first rise in temperature but is either maintained at about room temperature value or increases before the final decrease occurs.

The increased strength produced by rolling cold or at blue heat (300 degees Cent.) is maintained throughout a considerable temperature range, but these effects may be removed by suitable annealing. High proportional limit exists while tempering cold rolled plate at 300 degrees Cent. or after cooling to room temperature, an effect which

can be used to advantage in the production of cold finished products, such as thin walled seamless steel tubes where bluing after the final cold pass will produce a high elastic ratio.

Some effects of tensional elastic overstrain are also described in detail. Among the tests made are those showing that the proportional limit can be made to approximate the tensile strength by overstraining successively at blue heat with gradually increasing loads. Differences in behavior of overstrained steel upon etching are observed depending upon whether the overload is applied above 465 degrees Cent. or below blue heat (300 degrees Cent.). Likewise, the effect of decrease in rate of loading is different in these two temperature ranges, though little variation in tensile properties was observed when tests were performed 30 times as fast as would ordinarily be the case.

Wear of Steels

Several tests have been conducted by the Bureau of Standards to determine the resistance to wear of hardened and tempered chromium steels. It was noticed that while the so-called standard hardened specimen, which was run on the upper shaft of the testing apparatus, invariably had a polished surface at the conclusion of every test, the bottom specimen, especially the tempered specimens, presented a dull appearance which was presumed to be caused by abraded articles sticking to the specimen. It seemed, therefore, that specimens with this dull mottled appearance would show a loss of weight less than the actual loss. To prove this several tests were made of Ketos steel running the standard hardened specimen on the lower shaft and the tempered specimens on the upper shaft. The curve of rate of wear versus tempering temperature obtained was similar to the previous curve but showed a greater rate of wear.

The tempered specimens under the last-named conditions were free from abraded material at the end of the tests. Efforts will be made to prevent the adherence of the abraded metal particles to the specimen.

The Effect of the Presence of Oxygen in Iron-Carbon-Manganese-Sulphur Alloys Upon the Forging Properties

A short series of iron-sulphur-manganese alloys has been prepared by melting under air, for comparison with a portion of a similar series prepared in the Arsem vacuum furnace, in order to determine whether the presence of oxygen in the alloy influences the sulphur limit and the manganese-sulphur ratio for successful forging.

It has been necessary to develop a new type of refractory crucible for use in preparing the carbon alloys of the vacuum-fused series of this investigation. Manganese crucibles are not desirable on account of the slagging out of sulphur.

Zirconium silicate crucibles served satisfactorily for the preparation of the iron-sulphur and iron-sulphur-manganese alloys, but with the ad-

dition of carbon, the alloys are contaminated by silicon. Tests are now in progress to determine the suitability of a crucible made chiefly of zirconium oxide.

Tests of Thermocouples

Life tests of the pure platinum and platinum-rhodium wire prepared at the Bureau of Standards for thermocouples have been carried out by the heat division. These tests are the same as those applied to commercial couples which were recently reported by Fairchild and Schmitt in *Chemical and Metallurgical Engineering*. Results thus far obtained indicate that couples of material purified, melted and drawn to wire at the Bureau are appreciably superior to the best commercial couples previously tested. A paper describing the preparation and life tests of such couples has been written and will be offered for presentation at the spring meeting of the American Electro-chemical Society. Another paper describing the general platinum metals investigations, now in progress at the Bureau, has also been prepared for presentation at the same meeting.

Routine Magnetic Testing

The routine magnetic testing of the Bureau has been placed upon a new basis which provides for two classes of test. Class A will be restricted to specimens which are sufficiently uniform in dimensions and magnetic properties along their length to justify the employment of test methods of the highest accuracy and which are intended for use as standards for the calibration of testing apparatus, or for other uses where high precision is necessary. For this class of test, two specimens are required of the same material, one of which is used as an auxiliary. Class B test will be made in general in cases where the material is not sufficiently uniform to justify the use of precision methods or where the highest accuracy is not necessary.

Cutting Tests of High Speed Steel

Five types of steel are to be considered in this investigation, and the second steel of the series has been heat treated for the first set of tests in which hardening temperature is the variable. In connection with this work a number of treatments were applied to a single heat of high-tungsten low-vanadium steel to determine whether so-called fish scale or flaky fractures could be produced intentionally irrespective of the quality of metal as has been claimed. Normal fractures were obtained, however, in all cases, but these tests will be supplemented by further work with steel of questionable quality. The question was brought up for discussion at a recent meeting of the American Society for Steel Treating at Rockford, Illinois.

Erection of a 10,000,000-Pound Testing Machine

For many years a small branch of the Bureau of Standards has been maintained in Pittsburgh for the testing of structural materials. Recently it was decided to concentrate all of this work in Washington with the result that for some months past the equipment of the Pittsburgh laboratory has been in process of removal from its old site to the permanent location at the Bureau.

An interesting part of this work has been the transportation and

erection of the 10,000,000-pound Olsen testing machine. This work is now completed and the machine has been calibrated and is now ready for use. Advantage was taken of the dismantling of this machine to prepare complete drawings of the various parts for future use.

Etching Reagents for Alloy Steels

Considerable attention was paid during the past month to the problem of finding an etching reagent by which chromimum carbide could be distinguished from vanadium carbide, in a positive and satisfactory manner. Only one out of about 20 of the reagents tried seemed likely to be of much use in this connection. This is a hot solution of potassium permanganate and sodium hydroxide, etching in which for one minute darkens chromium carbide to a strong brown-red or brown color, or rather, the carbon is eaten out giving the walls of the cavity thus formed a dark brown-red color, while vanadium carbide remains uncolored and apparently unattacked.

Another but less positive means of distinction is that obtained by electrolytic etching with a weak current in a dilute aqueous solution of ammonia or sodium hydroxide. The chromium carbide is eaten out leaving a dark brown-red or brown cavity, while the vanadium carbide is eaten out apparently at a slower rate leaving cavities which appear light and not at all darkened.

Recent Publications of the Bureau of Standards of Especial Interest to Our Readers

Scientific Papers

S 452 Structure of martensitic carbon steels and changes in microstructure which occur upon tempering. H. S. Rawdon and Samuel Epstein.

S 453 Preparation and properties of pure iron alloys: 1. Effects of carbon and manganese on the mechanical properties of pure iron. Robert P. Neville and J. R. Cain.

S 457 Gases in metals: 1. The determination of combined nitrogen in iron and steel and the change in form of nitrogen by heat treatment. L. Jordan and F. E. Swindells.

S 458 Apparatus for the determination of the magnetic properties of short bars. M. F. Fischer.

Technologic Papers

T 219 Effect of temperature, deformation, and rate of loading on the tensile properties of low-carbon steel below the thermal critical range. H. J. French.

T 221 Magnetic susceptibility and iron content of cast red brasses. L. H. Marshall and R. L. Sanford.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

NEW QUESTIONS

QUESTION NO. 71. How do the physical properties compare between a 0.35-0.45 per cent carbon acid open-hearth steel and an alloy steel of either 3.5 per cent nickel or 1.5 per cent nickel and 0.50 per cent chromium neither heat treated?

QUESTION NO. 72. What elements are conducive to good electric butt-welding of steels?

QUESTION NO 73. Does electric butt-welding destroy the physical properties developed in a steel which has been heat treated prior to the welding operation?

QUESTION NO. 74. Why shouldn't a bar of steel rolled from a locomotive axle be better than one rolled direct from the billet made from the original ingot?

QUESTION NO 75. How much would the cold drawing of any steel affect its hardness when only one or two, light passes are given for the purpose of sizing only?

ANSWERS TO OLD QUESTIONS

QUESTION NO. 27. What is the function of the high phosphorus and the high sulphur content in the so-called automatic screw stock steel?

QUESTION NO. 56. Which is the best method of producing large forgings, pressing or hammering?

ANSWER. By John J. Crowe, metallurgist, Philadelphia.

There are practically no differences in the properties of properly hammered or pressed forgings, but the problem resolves itself into one of tool design.

Presses of large capacity are better suited for the working of large forgings and are therefore used. A hammer of same capacity as a 10,000-ton

press would shake windows out of houses within a radius of a mile, whereas, a press can be operated without appreciable vibration.

QUESTION NO. 57 Does repeated heating just above the critical range with subsequent quenching, of a steel specimen injure its physical properties?

ANSWER. By John J. Crowe, metallurgist, Philadelphia.

The repeated heating of ordinary forging steels to just above the critical range with subsequent quenching, does not injure their physical properties, but may under some conditions greatly improve them. Mr. Fry, metallurgist of the Standard Steel Co., has published results on specimens taken from a forging which was originally a six-inch cube, which had been quenched approximately 500 times. The results show the materials to have excellent physical properties and quite strongly indicates that they have not been lowered by the repeated quenchings although the specimen is now almost a sphere instead of a cube. There may, of course, be changes in the surface layer of the metal due to the furnace atmosphere.

QUESTION NO. 59. Is a sulphur content of 0.067 per cent detrimental to the proper carburizing of a low carbon steel having a low manganese and phosphorus content?

QUESTION NO. 62. What is the difference between annealing and normalizing steel?

ANSWER. At times the terms annealing and normalizing are used rather loosely to mean either one or the other of the following definitions. The American Society for Steel Treating has a committee working on nomenclature and this committee will undoubtedly establish definitions of these two terms.

The Society for Automotive Engineering have adopted the following definitions of these terms.

Normalizing.—A uniform heating above the upper critical temperature followed by cooling freely in air.

Annealing.—A uniform heating above the upper critical temperature followed by slow cooling as desired.

QUESTION NO. 64. To what extent can the deep etching of specimens of steel be applied to routine examination of incoming material?

QUESTION NO. 66. What method and procedure is used in brazing Stellite to carbon steel?

QUESTION NO. 67. What is the reason for the fact that a piece of steel quenched in brine will be harder than the same piece of steel would be if quenched in water, providing that the quenching temperatures and quenching medium temperatures are the same in each case?

QUESTION NO. 68. What is the correct temperature of heating for forging, a .40-.50 per cent carbon steel into automobile crankshafts?

QUESTION NO. 69. Is sulphur up to .10 per cent detrimental to the quality and physical properties of an automotive steel?

QUESTION NO. 70. Is it possible to have a specimen of steel in such a condition that it will show in any one field observed under a microscope at 100 diameters magnification, ferrite, pearlite, sorbite, troostite and cementite?

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

SERVICE FOR MEMBERS

The Library Bureau of the American Society for Steel Treating is operated to give to the members quickly, reliably and at the minimum expense the following service:

1. A complete copy of the magazine article referred to in any periodical you may be reading.
2. A translation of foreign articles that would help you with your work.
3. A list of references to books and articles on any metallurgical subject.
4. Informing the members of new articles of interest to them as an engineer.

The Library Bureau makes the entire field of literature available to every member, distance is eliminated, for it will copy the desired information and send it to you. It also helps the busy man by supplying information without any expenditure of his time. The charge for this personal work is merely its cost.

The Library Service does not obtain any profit from the work, but does this to make the information contained in the large libraries with which it has connection available to every member. The rates are as follows:

Photo Print Copies of articles, drawings, etc., 25c per 10 x 14-inch sheets.

Searches, abstracts, etc., $2.00 an hour.

Translations, $6.00 per thousand words for French of German; $7.50 and upward for other languages.

Reference card service, giving reference to current magazine articles, $10.00 a year in advance, and 5c for each card mailed.

Members desiring to avail themselves of this service should address Library Bureau, American Society for Steel Treating, 4600 Prospect Ave., Cleveland, Ohio.

HEATING AND COOLING LARGE INGOTS. By F. E. Bash, in *Iron Trade Review*, Feb. 22, 1923, page 594.

This article gives the results of experiments which have been made to obtain data for determining the maximum rate of heating ingots without injury, and states that reliable figures are available on twenty-four, thirty and forty-five inch sizes.

CALORIFIC VALUE OF STEEL-MAKING ELEMENTS. By H. D. Hibbard, in *Iron Age*, Vol. 111, No. 5, Feb. 1, 1923, page 347.

In this article the author explains the actions of phosphorus, manganese, chromium and other metals in steel processes, and points out the peculiarities of sulphur.

SPECIFICATIONS FOR DIE-BLOCK STEEL. In *Forging and Heat Treating,* January, 1923, page 47.

The above was taken from the *Drop Forger* (British), November, 1922 This article gives a report of the investigation of the specifications for die-block steel and outlines the desirable fundamental properties. It also gives the effect of alloying elements upon strength, machinability and heat treatment.

STRUCTURE OF CHROMIUM-NICKEL STEEL. By Messers. H. B. Pulsifer and O. V. Greene, in *Chemical and Metallurgical Engineering,* Vol. 28, No. 8, Feb. 21, 1923, page 354.

In the article are given a series of micrographs which fail to show any change in structure in quenched chromium-nickel steel after various draws, in spite of the large differences in the physical properties. The article also points out the precautions necesary in etching and photographing.

NOTES ON THE HEAT TREATMENT OF HIGH-SPEED STEEL. By H. K. Ogilvie, in February, 1923, *Railway Journal,* page 16.

The above notes were taken from a paper read before the Iron & Steel Institute (British) recently.

The author in presenting his article made some good suggestions stating that it is not good practice to make large, thin cutters direct from forged bars unless the bore of the cutter is extremely wide, it being preferable to use a medium sized ingot and forge it until is about four or five inches round.

THE MAGNETIC CHANGE A_2 IN SILICON AND CHROMIUM STEELS. By Howard Scott, Associate Physicist, Bureau of Standards. In Vol. 28, No. 5, Jan. 31 1923, *Chemical and Metallurgical Engineering,* page 212-215.

In the above article the author points out that since the carbon change points is at a higher temperature than the magnetic change point, it is impossible to rely upon the loss of magnetism to indicate the proper hardening temperatures for silicon and chromium steels. Several tables are given showing the inverse rate heating curves of silicon and chromium steels.

X-RAY EXAMINATION OF STEEL CASTINGS. By H. H. Lester, Watertown Arsenal, in *Chemical and Metallurgical Engineering,* Vol. 28, No. 6, Feb. 7, 1923, page 261.

The above article states that it is possible to locate 1/16-inch flaws in steel three inches thick with a 30-minute exposure from a commercial X-ray tube, and also that correspondingly smaller defects can be likewise revealed in thinner sections.

COMPOSITION AND MANUFACTURE OF DIE-BLOCK STEEL. By Chas. McKnight, International Nickel Co., New York City, in *Forging and Heat Treating,* January, 1923, page 44.

This article discusses the merits of various steels used for die-blocks and compares straight carbon and alloy steels. It also points out the importance of careful heat treatment.

EFFICIENT CASE HARDENING BOXES. By L. C. Dunn, Montgomery Chemical Co., Detroit, Mich., in *Forging and Heat Treating,* January, 1923, page 53.

The above article points out that the design of efficient case hardening boxes varies according to the type of furnace and the work to be treated. It also compares plain carbon and alloy boxes.

HEAT TREATMENT AND THE STRENGTH OF STEEL UNDER REPEATED STRESSES. By J. W. Harsch, University of Illinois, in *Forging and Heat Treating,* January, 1923, page 57.

In the above article the author discusses the effect of heat treatment on the fatigue strength of steel, and describes in detail machines and methods. He also points out the influence of structure on fatigue resisting properties.

THE METALLURGICAL MICROSCOPE. By Dr. Walter M. Mitchell, Philadelphia, Pa., in *Forging and Heat Treating,* January, 1923, page 63.

This is part 1 of a series of articles to be written on this subject. The article discusses the microscope as applied to the examination of metallic specimens. It also explains at considerable length the use and limitations of the various lenses.

THE AUTOMATIC CONTROL OF TEMPERATURE IN INDUSTRIAL FURNACES. By Messrs. W. Trinks and S. A. Henderson, Carnregie Institute of Technology, in *Forging and Heat Treating,* January, 1923, page 68.

This article discusses in detail the various types of automatic temperature controls as applied to furnaces heated by electricity, gas or oil. It also points out the importance of the location of the thermo-couple.

STRESS IN ELECTRIC-RAILWAY MOTOR PINIONS. By Messrs. Paul Heymans, Cambridge, Mass., and A. L. Kimball Jr., Schenectady, N. Y., in *Mechanical Engineering,* Vol. 45 No. 2, February, 1923, page 93-96.

The above article includes the results of a scientific study taken by the General Electric Co., for the development of superior electric railway motor pinions. The work was performed at Massachusetts Institute of Technology using apparatus belonging to General Electric Co. for stress determination in transparent models by the photo-elastic method. Some of the tests were made at Schenectady and close contact was kept with the railway motor department and the research laboratory at Schenectady. A description and discussion of the photo-elastic method is given, and the causes of ruptures of given types of gear pinions used in electric-railway motors are discussed.

THERMAL PROPERTIES OF ALUMINUM-SILICON ALLOYS. By Junius D. Edwards, Assistant Director of Research, Aluminum Co. of America, in *Chemical and Metallurgical Engineering,* Vol. 28, No. 4, January, 1923, pages 165-169

In this article is given the accurate determination of the densities of aluminum alloys containing variable amounts of silicon. It also gives data on crystallization shrinkage as well as the total solid shrinkage and the tendency to form pipes.

OSCILLATIONS AND FATIGUE OF SPRINGS. By Joseph Kaye Wood, Western Electric Co. In *American Machinist,* Vol. 58, No. 4, Jan. 25, 1923, pages 155-159.

This article points out that internal friction is the chief cause of fatigue. It also shows that there are two resistances in hysteresis. This article gives also the practical uses of overstrain.

GRAY IRON CASTINGS FROM THE ELECTRIC FURNACE. By Larry J. Barton, in *Iron Age,* Vol. 111, No. 4, Jan. 25, 1923. Pages 269-273.

The author in the above article explains how it is possible to produce gray iron castings commercially in an electric furnace. He also gives the acid and basic practice and gives the recommended practice, and describes the heat treatment of iron castings.

THE METALLURGY OF SEMISTEEL. By David McLain in *Western Machinery World,* February, 1923, pages 60-63.

The object of the above article is to give some plain proofs about semi-steel, and many of the statements made deal with historical facts dating back fifty years. The article states that the name semi-steel has been misused for many years and will continue to be as long as there is no interest shown to really find out what it is.

FUEL GAS QUESTION IN STEEL INDUSTRY. By F. J. Denk in *Iron Age,* Feb. 8, 1923, page 401.

The article points out that B. t. u. values in comparing fuels can not be depended upon since it has been found that the efficiency of a gaseous fuel does not depend upon its heat value, but upon its pyrometric efficiency. Combustion curves are given, which show the determination and comparison of the gases used mostly in the steel industry. These further show that with the exception of producer gas, natural gas has the lowest flame temperature of the gases taken into consideration. A table is also given which shows the amount of steam which can be raised by waste gases from one pound of coal gasified.

ELECTRIC HEATING ADVANCE RAPID. By F. A. Hansen, Westinghouse Electric & Mfg. Co. In *Iron Trade Review,* Feb. 15, 1923, pages 512-514.

The above article states that much electrical heating in the iron and steel industry has taken place in the past few years, and further points that the principal advantages of electricity for operating are that it is economical, clean, and easy to take care of.

OFFERS FIELD FOR ELECTRIC FURNACES. By Lansing W. Hoyt, Trade Commissioner, Shanghai, China. In *Iron Trade Review,* Feb. 15, 1923, page 515.

The author of this article discusses the iron and steel situation in China, and states that Shanghai is able to make electric steel at a moderate cost, and also that castings could be made for less than $35.00 per ton. There are no steel foundries in China.

News of the Chapters

SCHEDULED REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Boston—Second Tuesday
Bridgeport—Thursday between 20th and end of month
Chicago—Second Thursday
Cincinnati—Second Thursday
Cleveland—Fourth Friday, Cleveland Engineering Society Rooms, Hotel Winton; meeting at 8:00 p. m.
Detroit—Second and fourth Monday, Wing E., 15th Floor General Motors building.
Hartford—Friday nearest 10th of month
Indianapolis—Second Monday
Lehigh Valley—No regular night
New Haven—Third Friday
New York—Third Wednesday
Philadelphia—Last Friday
Pittsburgh—First Tuesday
Providence—No regular night. Nov. 10th, Dec. 12th.
Schenectady—Third Tuesday
Springfield—Third Friday
South Bend—Second Wednesday
St. Louis—Third Monday
Syracuse—No regular night
Tri City—Thursday
Washington—Third Friday
Rockford—Second Friday following the second Thursday

MEMBERSHIP AND ATTENDANCE CONTEST

The following arrangement of the chapters shows the percentage of increase of new members as of Feb. 1, 1923, based on the number of members each chapter had on Sept. 1, 1922. While practically all of the chapters have shown an increase in membership over that given in the last report, those printed in CAPS have passed others.

	Per Cent		Per Cent		Per Cent
1. Detroit	56.1	10. Buffalo	22.5	19. Chicago	12.0
2. NORTH WEST.	48.0	11. CINCINNATI	18.9	20. Pittsburgh	10.4
3. South Bend	44.0	12. New York	18.1	21. Springfield	10.3
4. Boston	35.0	13. Syracuse	16.4	22. ST. LOUIS	9.6
5. TRI CITY	34.2	14. Cleveland	16.1	23. NEW HAVEN	9.1
6. Philadelphia	32.0	15. WASHINGTON	15.0	24. Worcester	8.9
7. SCHEN'TADY	29.4	16. Rockford	14.6	25. Toronto	7.2
8. Lehigh Valley	26.8	17. Hartford	14.4	26. Rochester	0
9. Milwaukee	26.6	18. Indianapolis	14.3	27. Providence	0

Attendance At January Meetings

Only 18 chapters reported attendance at January meetings consequently only that number is listed below. The report of attendance for 6 meetings is necessary in order to qualify a chapter in the contest.

The following chapters did not report attendance at their January meetings. Boston, Buffalo, Cincinnati, Indianapolis, Lehigh Valley, Rochester, Schenectady, Springfield and Worcester.

New Haven had the largest percentage of members present (56.3 per cent). North West jumped from seventh in December to second place in January; Tri City also showed an advance. All of the chapters had over 30 per cent of their membership present at their January meeting.

The following gives the percentage of attendance at the January meetings of the chapters reporting. Chapters printed in CAPS show an increase in attendance:

	Per Cent		Per Cent		Per Cent
1. NEW HAVEN	56.3	7. Toronto	43.4	13. CLEVELAND	25.6
2. NORTH WEST	49.0	8. Rockford	42.0	14. Detroit	22.9
3. SYRACUSE	47.5	9. ST. LOUIS	32.7	15. Chicago	22.0
4. TRI CITY	46.8	10. Hartford	31.4	16. PITTSBURGH	17.4
5. South Bend	46.7	11. Philadelphia	30.9	17. Washington	17.0
6. Providence	44.4	12. MILWAUKEE	27.5	18. New York	14.5

Standing in the Contest

In order to determine the standing of each chapter in the contest it is necessary to add the percentage of attendance at the December meeting and at the January meeting and divide by 2 to get the average attendance for the two meetings. The average thus obtained is added to the percentage of increase in members obtained since Sept. 1 1922 to Jan. 30. This total is then divided by 2 to obtain the standing of each chapter in the contest inasmuch as attendance counts 50 per cent and increase in membership 50 per cent. For example, a chapter had 50 per cent attendance at December meeting and 60 per cent attendance at the January meeting which gives an average attendance of 55 per cent. The percentage of increase in membership of this chapter was 45 per cent—giving an average standing in the contest of 50 per cent.

On this basis we find the following to be the standing of the chapters on Feb. 1 in the Membership and Attendance Contest:

	Per Cent		Per Cent		Per Cent
1. South Bend	47.3	8. Providence	26.7	15. Cleveland	20.0
2. Detroit	46.0	9. New Haven	26.4	16. St. Louis	20.0
3. North West	44.5	10. Toronto	25.3	17. Washington	17.9
4. Syracuse	39.0	11. Cincinnati	24.2	18. Chicago	17.5
5. Tri City	37.5	12. Hartford	24.2	19. New York	16.7
6. Philadelphia	32.1	13. Milwaukee	23.5	20. Pittsburgh	14.1
7. Rockford	30.0	14. Springfield	21.3		

Never Too Late

As stated in the report in February TRANSACTIONS, it is never too late to get in this contest and land among the winners because several chapters that were not reported in the December report have taken

very high positions in this report. A little concentrated effort and a follow-up system to secure attendance at meetings will obtain desirable results.

New Members

There were 64 new members added to the roll of the society during the past month. This number was increased to 66 by the reinstatement of two members who had been dropped. However, this increase was offset by 29 members being dropped for non payment of dues—11 resignations and 1 death, making a total loss of 41. This leaves a net increase of 25 members.

Keep-Them-In Committee

Many chapters have organized Keep-Them-In committees and as soon as the secretary is notified that several members are in arrears and will be dropped for non payment of dues, this committee gets busy and endeavors to have them retain their membership in the society. It is believed that this committee can be so organized as to do very valuable work.

Based on the number of members in each chapter on Jan. 30 the following table shows the standing of the 27 chapters of the society. Those printed in CAPS have advanced their positions while those in italics have a lower position.

The standing is as follows:

1. Detroit
2. Chicago
3. Pittsburgh
4. Philadelphia
5. Cleveland
6. New York
7. Hartford
8. BOSTON
9. *Milwaukee*
10. Lehigh Valley
11. North West
12. Syracuse
13. *Worcester
14. *Indianapolis
15. St. Louis
16. Rockford
17. Tri City
18. WASHINGTON
19. CINCINNATI
20. **Buffalo*
21. *Schenectady
22. Springfield
23. Providence
24. South Bend
25. New Haven
26. Toronto
27. Rochester

*Tied

BOSTON CHAPTER

The following is a review of the activities of the Boston chapter of the American Society for Steel Treating for the past four months. The October meeting was held at the plant of the New England Metallurgical corporation at South Boston. This plant which is a very up-to-date heat treating plant was in actual operation during the meeting. The speaker for this meeting was J. W. Black of the Geometric Tool Co., New Haven, Conn., who presented a paper entitled, "Hardening 25 Years Ago and Today." Following this paper, E. E. Roberts of the New England Metallurgical corporation made a few remarks and then presented some demonstrations which included the "Bellis Lava Process" and other interesting hardening methods with up-to-date equipment. There were 38 members and 66 guests present at this meeting.

The November meeting was held at the works of the Boston Consolidated Gas Co., at which time W. W. Cummings of the gas company presented a capable paper entitled "Gas—Its Manufacture and Application to Furnaces." At this meeting the Boston chapter had as guests W. S. Bidle and W. H.

Eisenman, officers of the National society. As a feature of this meeting there was a model gas making plant on exhibition and in operation. Prior to the meeting a dinner was served at which the Boston chapter members and friends were guests of the Boston Consolidated Gas Co. There were 44 members and 97 guests present at this meeting making a total of 141.

The December meeting which had been planned as one of the best of the year was held at the Massachusetts Institute of Technology. Unfortunately this part of the country had been swept by a blizzard the day and evening of the meeting which prevented many of the members from being present. The speaker, Dr. G. B. Waterhouse, professor of metallurgy of the Massachusetts Institute of Technology presented an interesting and capable paper entitled "Basic Open Hearth Steel." Following Dr. Waterhouse's presentation, Prof. I. H. Cowdrey explained in detail the different testing machines and apparatus that were on exhibition and in operation in his laboratory at the Massachusetts Institute of Technology. The attendance at this meeting was 40 members and 52 guests.

The January meeting was held at the Blake & Knowles plant of the Worthington Pump & Machinery Corp. Owing to the facilities at hand it was decided to make this a dinner meeting inasmuch as the company maintains a large cafeteria for their employes, the use of which was extended to the chapter. The members and guests were welcomed to the plant by George P. Aborn, works manager, who gave a short outline of the history of the Blake & Knowles plant from its infancy. A short talk was given by Otto Nonnenbruch, assistant chief oil engineer on the subject of "Diesel Engines."

The main speaker for this meeting was W. J. Kunkel of the forge department of the Blake & Knowles works who presented a capable paper on "Forging." This paper brought out many interesting points. An interesting and profitable discussion followed its presentation. After the meeting the forge department was in operation and was open for the inspection of the chapter members. Forgings were made, which included large 2000-pound crankshafts down to small tool forgings. These operations were of great interest to the visitors. The advantages of the autogenous cutting torch in forge practice was likewise demonstrated as well as the welding of monel metal with the acetylene flame and the babbitting of high efficiency bearings for heavy duty engine work. About 49 members and 141 guests were present for this meeting.

The February meeting of the chapter was held on the twentieth at the plant of the Edison Electric Illuminating Co. A get-together dinner prior to the meeting was served at 6:30 p. m. in the dining room of the Illuminating company's plant. Following this dinner E. F. Collins of the General Electric Co., Schenectady, presented a paper entitled "Electricity, and Its Application to Furnaces and Heat Treating of Steel." This paper brought out many valuable points of interest to steel treaters. Inasmuch as considerable interest in the use of large electrically-heated heat treating furnaces has been shown by heat treaters in general, the information which Mr. Collins brought out was very valuable and instructive.

The March meeting of the chapter will be held on the twenty-second at the Franklin Union. The speaker for this meeting will be Mr. Homerberg on the subject of "The Microscope as an Aid in the Solution of Practical Steel Problems."

CHICAGO CHAPTER

The report of the February meeting of the Chicago chapter appears on page 592.

CLEVELAND CHAPTER

The Cleveland chapter of the society held a meeting on Feb. 19 in the rooms of the Cleveland Engineering society, Hotel Winton. The program for this evening was a round table discussion on the subject of "gears," dealing with the various steels used in making gears; the forging and rolling of gears; the machining of gears, including a discussion of the condition of material for efficient machining; the heat treatment of gears including the carburizing and tempering; grinding of gears including methods of grinding and finally the inspection of gears, including examples of defects usually found. Each of these subjects were introduced by members of the chapter, who are specialists on the particular subjects and many valuable points were developed during this discussion. Due to the wide scope of the program as outlined, it was impossible to finish all of the topics and those topics which were not discussed will be presented at a meeting later in the year.

CINCINNATI CHAPTER

The regular February meeting of the Cincinnati chapter was held on the twelfth, in the Ohio Mechanics Institute at which time E. E. Thum of *Chemical and Metallurgical Engineering*, New York City presented an interesting paper entitled "Educating the Metallurgist and the Management." Mr. Thum brought out some very important points regarding the relationship between the metallurgist and the executive, pointing out that it is of prime importance that the metallurgist prove to the management that his department is an asset and not a liability. This meeting was very well attended.

LEHIGH VALLEY CHAPTER

The Lehigh Valley chapter of the society held a meeting on March 1 at the public library, North Sixth and Church streets, Easton, Pa. F. R. Palmer of the Carpenter Steel Co. presented a very enlightening paper entitled "Tool Steel." Mr. Palmer is a very capable metallurgist and has had considerable experience in the study of tool steels. He brought out many points of interest as evidenced by the valuable discussion which followed this paper.

MILWAUKEE CHAPTER

The Milwaukee chapter of the American Society for Steel Treating held its regular monthly meeting Wednesday evening, Feb. 21, 1923, in the Blatz hotel.

The chapter was fortunate in having as speakers for this meeting W. H. Eisenman, national society secretary, and Dr. P. D. Merica, metallurgist, with the International Nickel Co.

Mr. Eisenman gave an interesting talk on matters of interest to the local chapters and the national society, pointing out the aims and aspirations of the society in its work for the future and how the local chapters assist in carrying the work forward.

Dr. Merica presented a very capable paper entitled "Nickel and Its Uses

in Iron and Steel." He brought out many valuable points showing how nickel was playing a most important role in the alloy steel field. This paper was very interesting and developed a large amount of valuable and instructive discussion.

About 75 members and guests were present at the meeting, many of whom were present at the get-together dinner which was served at 6:45 p. m.

NEW HAVEN CHAPTER

The New Haven chapter of the American Society for Steel Treating held its regular February meeting Friday evening the sixteenth, in the assembly room of the New Haven Gas Light Co. The speaker for this evening was R. A. Cole, mechanical engineer of the Norton company of Worcester, Mass., who presented a paper entitled "Grinding." Mr. Cole displayed samples of grinding wheels and material to be ground as well as the results obtained through the use of various types and grades of wheels. These samples were of considerable interest to the membership. This paper brought out many valuable points and aroused considerable interesting discussion. Preceding the meeting the usual informal get-together dinner was served in the Cafe Mellone at 6 p. m.

The New Haven chapter of the American Society for Steel Treating held its March meeting Friday evening, the second, in the plant of the Geometric Tool Co. J. V. Emmons, national treasurer and metallurgist for the Cleveland Twist Drill Co., presented his paper entitled "Machinability of Tool Steels." This paper was illustrated with stereopticon slides and brought out many points of interest and value to the members. W. H. Eisenman, national secretary, was present and gave a short talk on the affairs of the society.

The heat treating department of the Geometric Tool Co. was in full operation and a practical demonstration and talk was given to the members. An informal get-together dinner was served at the Cafe Mellone preceding the meeting.

NEW YORK CHAPTER

The New York chapter of the society held its February meeting on the twenty-first in the assembly room of the Merchants Association of New York, on the ninth floor of the Woolworth building. Due to the fact that the speaker, J. V. Emmons, metallurgist for the Cleveland Twist Drill Co. was unable to be present his paper entitled "Machinability of Tool Steels" was presented by one of the members of the chapter. His paper was a very capable presentation of the effect of the structure of tool steels on their machinability and brought forth much favorable comment and discussion.

NORTH WEST CHAPTER

The North West chapter of the American Society for Steel Treating held its January meeting on the thirtieth in the Manufacturers' club rooms. This was an open meeting for the discussion of case hardening with particular reference to automobile parts for the Ideal Manufacturing Co. A discussion

was led by a committee appointed at the last meeting and a number of practical problems were presented and considered. This meeting proved to be highly instructive and of value to those who had the privilege of attending.

The North West chapter of the society held its regular monthly meeting on Monday evening, Feb. 19 in the Manufacturers' Club of Minnesota. The speaker for this evening was Dr. P. D. Merica, metallurgist of the International Nickel Co., who presented a paper entitled, "Nickel; Its Metallurgy and Industrial Applications." Dr. Merica has had wide experience in the metallurgy of both ferrous and nonferrous metals having formerly been with the United States Bureau of Standards. He has had extensive experience both in research and actual practice and spoke with authority upon the subject of nickel and nickel alloys. His paper brought out many valuable points of information and was of great interest to all of the members and guests who had the privilege of hearing him.

W. H. Eisenman, national secretary of the society was present at this meeting and addressed the membership on numerous society matters of interest to both the national body and the local chapters.

This meeting was a joint meeting with the members of the Minnesota section of the American Chemical society.

PHILADELPHIA CHAPTER

The Philadelphia chapter held its regular meeting on Friday evening, Feb. 23, in the Engineers' club, at which time A. W. F. Green, chief of laboratory, John Illingworth Steel Co. and chairman of the chapter presented an interesting paper entitled "Rolling Steel, Why, and What Happens." This paper was illustrated with stereopticon slides. Mr. Green outlined the progress that steel takes from the time it is cast into the ingot until it is ready for shipment, describing why it is necessary to roll steel and also what happens during this rolling operation.

J. V. Emmons, metallurgist of the Cleveland Twist Drill Co. and treasurer of the national society was scheduled to present a paper entitled "The Uses and Abuses of Twist Drills" but due to Mr. Emmons' illness he was unable to be present for this meeting; however, the motion pictures illustrating this subject were exhibited. They proved to be of considerable interest to all. The usual get-together dinner was served at 6:30 p. m. in the club dining rooms at which there was a very good attendance.

PITTSBURGH CHAPTER

The Pittsburgh chapter of the American Society for Steel Treating held its February meeting on the sixth in the William Penn hotel. E. E. Thum, associate editor of *Chemical & Metallurgical Engineering,* presented a very interesting paper entitled "Educating the Metallurgist and the Management." Mr. Thum had presented this paper before several of the other chapters and at each of these presentations his paper brought forth much valuable discussion and comment. The usual get-together dinner was served preceding the meeting.

ROCKFORD CHAPTER

The Rockford chapter of the American Society for Steel Treating held its January meeting on the nineteenth at the Hotel Nelson. S. M. Havens,

one of the directors of the national society, visited the chapter and gave a talk on matters of interest pertaining to the national sociey and the local chapters outlining concisely the aspirations of the national body for the future.

James P. Gill, metallurgist for the Vanadium-Alloys Steel Co. was the main speaker for this meeting and he presented a very capable paper entitled "The Tempering of Tool Steel." This paper was most universally applicable to the work that many of the members of the Rockford chapter are doing each day and as a result brought forth much interesting discussion following its presentation. Mr. Gill, who is a very capable metallurgist, handled this subject in a most capable manner.

SOUTH BEND CHAPTER

In the face of a blizzard and zero weather, the South Bend chapter held its February meeting on the fourteenth at the LaSalle hotel, attended by 71 members and guests . Dinner was served at 6:45 p. m. in the College Inn. Following the dinner, F. A. Hurcomb, manager of the M & S department of the Studebaker corporation, South Bend, read a paper on "Problems in the Machining of Heat Treated Stock." Discussion on this comprehensive paper is to be held in March.

The main speaker of the evening was E. E. Thum, associate editor of *Chemical and Metallurgical Engineering,* New York City. His subject was "Educating the Metallurgist and the Management." Mr. Thum scored the present technical university system for the apparent effort to crowd the technical and metallurgical courses with irrelevant subjects. He also strongly advocated the extension of the time of technical courses to five or six years. In regard to the "education of the management" Mr. Thum advised a program of advertising directed to the "men higher up" in order that credit due the metallurgist for reduction of production costs and improvement of methods should be brought to their attention, raising the standard of the technical man in the estimation of the management.

Among the guests present were W. P. Woodside and M. R. Kavanagh assistant production manager of the Studebaker corporation.

E. J. Janitzky, chief metallurgical engineer of Illinois Steel Co., South Chicago, will be the speaker on March 14, the paper to be illustrated with moving picture films of the practices of that firm in the production of steel.

SPRINGFIELD CHAPTER

The Springfield chapter held its January meeting on Friday evening the twenty-sixth in the Chamber of Commerce building. Members of the Springfield chapter were very fortunate in having with them James J. Curran, metallurgist of the Henry Souther Engineering Co., Hartford, Conn., who presented a very interesting and instructive paper entitled "Inspection and Heat Treatment of Steel." This paper was well illustrated with stereopticon slides. Mr. Curran brought out many valuable points and showed the importance of proper inspection of materials prior to their manufacture into components and their subsequent heat treatment. This meeting was very well attended and proved of value to all.

ST. LOUIS CHAPTER

The thirty-second meeting of the St. Louis chapter of the American Society for Steel Treating was held at 7:30 o'clock the evening of Feb. 19, 1923.

This meeting was held in the science lecture room of the David Rankin Jr., school of mechanical trades, and an opportunity was afforded the various members of the society to see, first hand, the physical testing of normal and heat treated steel.

R. J. Josehans, of the David Rankin school co-operated in extending to the society complete use of their facilities, and chairman C. B. Swander, having prepared suitable test specimens, illustrated their physical testing.

A universal testing machine was used where the members had an opportunity to see for themselves the automatic plotting of the elastic limit in testing the strength of steel, both normal and heat treated.

Explanation was given the members concerning the elastic limit, tensile strength, elongation and reduction area as applied to physical testing of steel.

Many comments were made and a lively discussion took place regarding the effect of heat treating on the physical properties of steel.

A vote of thanks was given Mr. Josehans for the extension of the facilities and likewise, Mr. Josehans expressed his interest in an endeavor include a heat treating department in the Rankin school.

There being no further business, the meeting adjourned to meet again March 12.

SYRACUSE CHAPTER

The Syracuse chapter of the American Society for Steel Treating held its regular monthly meeting on Feb. 13 at 9 p. m. in the Yates hotel, at which time R. J. Allen, first vice president of the National society presented a very interesting and capable paper entitled "Inspection and Testing of Steel." Mr. Allen, who is metallurgist for the Rolls-Royce Co. of America has had wide experience in the inspection and treatment of materials for automotive purposes. This paper was exceedingly interesting and brought forth much valuable discussion. There were about 75 members and guests present to welcome Mr. Allen and participate in the discussion which followed his paper.

TRI CITY CHAPTER

The Tri City chapter of the American Society for Steel Treating held its February meeting in the Davenport chamber of commerce on Thursday, Feb. 22, at which time Dr. P. D. Merica, presented a paper entitled "Nickel, Its Metallurgy and Uses." Dr. Merica, who is a metallurgist of national reputation and one of the leading authorities on nonferrous metals was formerly connected with the Bureau of Standards. He has a large fund of information to draw from and he presented a most capable paper dealing with nickel and nickel alloys. This paper brought out a very interesting dis-

cussion. W. H. Eisenman, national secretary of the society and S. M. Havens, national director of the society were present and each addressed the membership on matters of interest pertaining to the national society and the local chapters. This meeting was well attended.

The Tri City chapter of the American society for Steel Treating held its regular monthly meeting, Feb. 22, 1923. The meeting was called to order at 8 p. m. by the chairman. He announced the results of the Membership and Attendance contest as of Feb. 1, 1923, showing that the Tri City chapter was in fifth place. The membership was urged to attend all of the meetings and to bring in prospective members.

S. M. Havens, one of the directors of the national society, presented some facts on the business condition of the society. He showed that our society is in a very healthy financial position and is able to put aside money for reserve funds.

W. H. Eisenman, National secretary of the society, described the various activities of the society, especially the TRANSACTIONS, which have grown, both in quality and quantity, during the past year. He also told of the plans for the next annual convention which will be held at Pittsburgh in October.

Dr. Paul D. Merica, director of Research, International Nickel Co. was the speaker of the evening and his subject was "Nickel, Its Metallurgy and Uses." Dr. Merica traced the history of the development of the metallurgy of nickel and described in detail the three principal methods now in use for the refining of nickel.

The principal use of nickel is in the production of nickel steels, over 50 per cent of the total nickel production going into the manufacture of nickel steels. The two principal uses of nickel steels are for armor plate and for automotive parts. Dr. Merica gave a series of curves and data indicating the value of using nickel in steel. It was shown that the "Merit Index" of a nickel steel was considerably higher than that of a carbon steel of equal carbon content and compared favorably with other alloy steels.

Other uses for nickel are in coinage, where a nickel copper alloy is used; German-silver, which is a nickel-copper-zinc alloy; and cupro-nickel. About five per cent of the total nickel production is used for nickel-plating.

The meeting was then turned over to A. H. Putnam, who started a round table discussion on the subject of "Drop Dies." There was considerable discussion of the merits of alloy steel dies as against carbon steel dies; also the relative values of forged steel dies as against cast steel dies.

A rising vote of thanks was tendered Dr. Merica for the excellent presentation of his subject. The meeting adjourned at 10:45 p. m.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A repesents Associate Member; S represents Sustaining Member; J represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

NEW MEMBERS

ADAMS, HARRY R., (A-1), 816 West Lake Street, Chicago, Ill.
ALLEN, R. D., (M-1), M. & S. Dept. Studebaker Corp., Plant No. 2 South Bend, Ind.
AMERICAN ENGINEERING CO., (S-1), Armingo Avenue & Cumberland Street, Philadelphia, Pa.
APPS, WILLIAM, (M-2), c/o Autocar Co., Ardmore, Pa.
ARVIDSON, G. ARTHUR, (Jr.-2), 1708 11th Street, Moline, Ill.
BARNEY, M. H., (M-1), 212 Davis Street, Syracuse N. Y.
BEEBE, S. C., (M-2), 90 Atkins Street, Meriden, Conn.
BENSON, SIMON, (M-1), c/o Miehle P. P. & Mfg. Co., 14th & Roby Streets, Chicago, Ill.
BLOCKS, EMIL C., (M-2), 1743 N. Troy Street, Chicago, Ill.
BOCK, E. W., (A-1), 611 Majestic Bldg., Milwaukee, Wis.
BOCKENFELD, LOUIS A., (Jr.-2), 1337 W. 7th Street, Davenport, Iowa.
BURDETT, D. D., (M-2), 2974 Bershire Road, Cleveland Heights, Ohio.
BURNETT, FREDERICK, (M-2), 43 Victoria Street, Toronto, Ont., Can.
BUSCH, EDWARD A., (A-1), Box 81, Dayton, Ohio.
CAMPBELL, T. A., (M-2), Remington Arms Co., Inc., Bridgeport, Conn.
CINCINNATI BICKFORD TOOL CO., Oakley Cincinnati, Ohio. Att. of A. H. Tuechter, Pres.
CONNER, CHAS. M., (A-1), 2224 Market Street, Philadelphia, Pa.
CONSOLIDATED MACHINE TOOL CO. OF AMERICA, 2300 Vine Street, Philadelphia, Pa. Att. of E. J. Rollings.
EADES, ENOS, (M-2), Rome Mfg. Co., Rome, N. Y.
ELIASON, AUGUST, (M-1), 10463 127th Street, Richmond Hill, Long Island City, N. Y.
ELLIOTT, WM. P., (Jr.-2), 129 S. Catherine Avenue, LaGrange, Ill.
FAHRENWALD, F. A., (M-1), 1692 Glenmount Road, Cleveland, Ohio.
FAULK, WM. M., (M-1), Yellow Sleeve Valve Engineering Co., E. Moline, Ill.
FOWLER, F. W., (M-2), Barber-Colman Co., Rockford, Ill.
FRASER, W. J., (M-2), 10 Sylvan Avenue, Toronto, Ont., Can.
GALBRAITH, HARRY B., (M-2), 1214 10th Street, Rockford, Ill.
GLAB, PETER, (M-1), 502 E. Jefferson Street, Syracuse, N. Y.
HALL, L. NORRIS, (S-1) c/o L. Norris Hall, Inc., 940 Front Street, Philadelphia, Pa.
HAMMERSLEY, JOHN, (M-8), 2130 Lakeview Avenue., Detroit, Mich.
HARRITY, EUGENE E., (M-1), 107 Camp Avenue, Braddock, Pa.
HARTEL, ANDREAS, III, (M-2), General Motors Research Corp., Dayton, Ohio.
HASSAN, A. A. Jr., (M-2), Crucible Steel Co. of America, Harrison, N. J.
HEARTLINE, E. H., (M-2), 315 12th Street, Moline, Ill.
HINDE, WILFRID, (Jr.-1), Y. M. C. A., Moline, Ill.
HISCOX, A. G. (M-10), Western Automatic Machine Co., Elyria, Ohio.
HOBBS, D. B., (Jr.-11), 407 Thorn Street, Warren, Ohio.
HOWAT, JOHN C., (M-2), R. D. Nuttal & Co., Pittsburgh, Pa.

HOWELL, LEE A., (M-1), 623 Park Avenue, Syracuse, N. Y.
HAZELTON, R. T., (M-1), Cincinnati Shaper Co., Elm & Gerrard Streets, Cincinnati, Ohio.
HULL, D. R., (M-1), Anaconda American Brass Co., Ltd., Toronto, Ont., Can.
JENNINGS, W. H., Jr., (M-1), Brown-Lipe-Chapin Co., Syracuse, N. Y.
KINITE CO., (S-2), Milwaukee, Wis., Att. of Mr. Tatum, Mgr.
KLICK, V. L., (M-12), 121 Sterrett Avenue, Covington, Ky.
KOHLER, CLEMENT, (M-12), 3236 Columbus Avenue, Minneapolis, Minn.
LAFFIE, J. T., (M-2), 476 Capitol Avenue, Hartford, Conn.
LATHROP, D. W., (M-2), Canadian Atlas Crucible Steel Co., Welland, Ont., Can.
LATUS, HARRY J., (M-3), 865 9th Avenue, Milwaukee, Wis.
LAURENT, HOWARD, (M-2), Box 123, San Bernardino, Cal.
LODGE & SHIPLEY MACHINE TOOL CO., 355 Colerain Avenue, Cincinnati, Ohio. Att. of Mr. J. W. Carrell, V. P.
LOVEJOY, FREDERICK, (A-2), 128 Sidney Street, Cambridge, Mass.
LUCAS, H., (M-1), Apt. A-414 W. Washington, South Bend, Ind.
LUERSSEN, G. V., (M-1), Carpenter Steel Co., Reading, Pa.
MARSHALL, L. K., (Jr.-1), East Walpole, Mass.
MARTIN, H. E., (M-10), 870 Lathrop Avenue, Detroit, Mich.
MARTIN, J. F., (M-2), Bellevue Mfg. Co., Bellevue, Ohio.
MARINO, F. P., (M-2), 2437 Emerson Avenue, S., Minneapolis, Minn.
McALLISTER, ROBERT J., (M-1), 5621 Elliott Street, Philadelphia, Pa.
McCRUDDEN, F. R., (Jr.-1), 353 W. 2nd Street, Moorestown, N. J.
McKAIG, W. WALLACE, (Sub-1) Cumberland Steel Co., Cumberland, Md.
McPHEE, RALPH W., Henry Pels & Co., 90 W. Street, New York City.
MILLER, D. W., (M-2), 1517 Sherwin Avenue, Chicago, Ill.
NELSON, ANDRUS, (M-1), Deere & Mansur Co., Moline, Ill.
O'BRIEN, LAURENCE J., (Jr.-1) 719 E. Woodlawn Avenue, Philadelphia, Pa.
OLSEN, GUST Jr., (M-2), 1814 Farnum Street, Davenport, Iowa.
PARDIE, FRANK D., (M-1), 925 W. Onondaga Street, Syracuse, N. Y.
PRIESTER, CHAS. J., (M-1), Schoder & Lombard, 202 Centre Street, New York City.
RAUB, CLIFFORD A., (Jr.-2), 1423 Columbia Road, Washington, D. C.
REARDON, ARTHUR, S., (M-1), 67A, Enmore Road, Enmore, N. S. W. Australia.
ROCK ISLAND PLOW CO., (S-1), Rock Island, Ill. Att. of J. L. Irving.
SANFORD, C. G., (A-2), c/o Wm. Jessop & Sons Co., Inc., Boston, Mass.
SATTER, F. N., (A-2), 968 Eddy Road, Cleveland, Ohio.
SCHEID, A. J., (M-2), 707 Delaware Street, Minneapolis, Minn.
SCHWEITZER, CHAS., (M-2), 302 Hartson Street, Syracuse, N. Y.
SCHULTZ, C. H., (A-1), 4021 Northminster Street, N. S. Pittsburgh, Pa.
SMITH, HERBERT A., (M-2), c/o Autocar Co., Ardmore, Pa.
SMITH, JOHN G., (Jr.-1), 6701 N. 12th Street, Philadelphia, Pa.
SPRINGER, J. HALL, (M-12), 235 Bryant Avenue, Syracuse, N. Y.
SQUIRES, JOHN, (M-2), c/o Maxwell Motor Corp., Detroit, Mich.
STARINSKY, M. C., (M-2), 2825 Monroe Avenue, Cleveland, Ohio.
SUTPHEN, MARTIN, (M-1), 102 Pickett Street, Syracuse, N. Y.
THOMAS, E. L. (A-12), Consolidated Rendering Co., 40 N. Market Street, Boston, Mass.
THOMPSON, L., (M-1), 1600 S. State Street, Syracuse, N. Y.
THURSTON, P. R., (A-2), 1838 E. 101st Street, Cleveland, Ohio.
LIBRARY OF TOHOKU, (Sub-1) Imperial University, Sendai, Japan.

VERPOORTEN, PETER, (M-1), 318 Washington Street, Hoboken, N. J.
WEESNER, C. W., (M-2), Trumbull Steel Co., Warren, Ohio.
WESTERN ELECTRIC CO., (Sub-1), Hawthorne Station, Chicago, Ill.
WESTINGHOUSE ELECTRIC & MANUFACTURING CO., (Sub-9) Research Laboratory, Ardmore Blvd., E. Pittsburgh, Pa.
WICKSTROM, A. H., (M-2), 718 Newell Street, Kenosha, Wis.
WILLIAMS-WHITE COMPANY (S-2), Moline, Ill.
WIRTEMBURG, G. H., (M-1), 181 Elm Street, Meriden, Conn.
ZIMMER, E. B., (M-1), 16623 West Park Avenue, Cleveland, Ohio.

CHANGES OF ADDRESS

ADELBERG, A. R., from Cyclops Steel Co., Broadway, New York City, to 1421 Arch St., Philadelphia, Pa.

BOYLE, JOHN D., from Newport Ave., Detroit, Mich., to Continental Motors Corp., Muskegon, Mich.

CHERRY, R. M., from N. 50th St., Philadelphia, Pa., to General Electric Co., Witherspoon Bldg., Philadelphia, Pa.
CHRISTIAN, R. E., from Elmhurst Ave., Highland Park, Mich., to 341 Tuxedo Ave., Highland Park, Mich.
COMSTOCK, G. D., from Stanley St., New Britain, Conn., to Suite E22-208 Farmington Ave., Hartford, Conn.
COOPER, CLARK JR., from Box 414, Millersburg, Pa., to 4130 Parkside Ave., Philadelphia, Pa.

GARDINER, F. E., from Crucible Steel Co. of America, 162-5 Richmond St., W. Toronto, Canada, to Hiram Walker & Sons Metal Products Co., Ltd., Walkerville, Ont., Can.

HARTLEY, W. T., from Atlas Crucible Steel Co., 632 Washington Ave., Dunkirk, N. Y., to 3882 W. 36th St., Cleveland, Ohio.
HOLMES, J. Q., from Nordyke & Mormon Co., Indianapolis, Ind., to 1031 N. Pennsylvania Ave., Indianapolis, Ind.

JAYME, J. PHILLIP, from Labelle Works, Crucible Steel Co. of America, Pittsburgh, N. S. Pa., to Crucible Steel Co. of America, P. O. Box 11-Grand Central Station, New York, N. Y.

LANE, H. M., from Owen Bldg., Detroit, Mich., to No. 333 State St., Detroit, Mich., c/o H. M. Lane Co.
LARIME, E. J., from 5144 Belvidere Ave., Detroit, Mich., to 3071 Chalmers Ave., Detroit, Mich.
LASCHUK, S., from 904 W. Milwaukee Ave., Chicago, Ill., to 835 N. Robey St., Wicker Pk. Station, Chicago, Ill.
LEARMOUTH, W. J., from 8340 Dexter Blvd., Detroit, Mich., to 2035 Glynn Court, Detroit, Mich.
LEE, I. H., from 1439 W. Grand Blvd., Detroit, Mich., to Studebaker Corp., Detroit, Mich.

MACHOLL, E. A., from 7836 Lafayette, Detroit, Mich., to Standard Scale Co., Detroit, Mich.
MAIN, W. C., from 1985 E. 105th St., Cleveland, Ohio, to 10816 Columbia Ave., Cleveland, Ohio.
McANIFFE, H. F., from Holmes, Pa., Del. County, to 80 Lilac St., Buffalo, N. Y.
McGREGOR, HARRY, from 1124 Detroit St., Flint, Mich., to 806 Prospect St., Flint, Mich.
MEYERS, A. L., from R. K. Le Blond Machine Co., Edwards & Madison Rds., Cincinnati, Ohio, to Hill Clark Co., Chicago, Ill.

NORTHRUP, H. B., from Diamond Chain Mfg. Co., Indianapolis, Ind., to 3730 Park Ave., Indianapolis, Ind.

SHAW, G. M., from 1517 Continental Bldg., Baltimore, Md., to 4215 Wickford Rd., Roland Park, Baltimore, Md.
SPITTAL, CHAS. W., from 819 Washington Ave., Dunkirk, N. Y., to 1353 Marlowe Ave., Lakewood, Ohio.
SULLIVAN, L. J., from 309 First St., Keyport, N. J., to 25 Oak Ave., Myrtle Beach, Milford, Conn.
TOPHAM, RICHARD A., from 12 Ray St., Schenectady, N. Y. to General Electric Co., Testing Laboratory, Lynn, Mass.
VOIGT, J. S., from Plant 3, Timken Detroit Axle, Detroit, Mich., to 10037 Dalrymple, Detroit, Mich.
WADLUND, A. P. R., from 30 Fairview St., Hartford, Conn., to 1087 Blvd., Hartford, Conn.
WHITEHEAD, WM. A., from 3040 Warren Ave., Chicago, Ill., to 465 Commonwealth Ave., Boston, Mass.
WRIGHT, F. G., from 1518 Euclid West, Detroit, Mich., to 396 Cortland Ave., Highland Park, Mich.

TRANSACTIONS

of the

American Society for Steel Treating

Vol. III Cleveland, April, 1923 No. 7

STICKERS OR SLIDERS

ONE of the truisms of life is the saying "A Friend In Need Is A Friend Indeed." Yet, there are few of us who have not had the lamentable experience of finding that those who lay strongest claim to being friends utterly fail to live up to the requirements of friendship when the occasion arises for them to demonstrate the sincerity of their claim.

It is fortunate that there comes in the lives of all men such events as require an alleged friend to demonstrate whether he belongs in the class of "stickers" or "sliders." The ones who slide away from your signal of hope will surprise you and the ones who stick by you in adversity, likewise will surprise you, because the ones from whom you expected so much will show such light regard for the principles of friendship, while those from whom you expected little, prove to be possessors of the greatest adhesive qualities. Yet, we would not have you think you should regard all friends with a feeling of doubt, but we would advise you make as many friends as possible so that if the occasion arises when the test is necessarily carried out, you may have a larger proportion of "stickers" than of "sliders" on your list.

And that point brings up the question "How are we going to make more friends?" We all agree that a correspondence course in friendship is not possible nor would it obtain satisfactory results because it leaves out of consideration the personal touch, the personal element, which is so necessary for a completion and refinement of friendship's possibilities.

There are opportunities and ways by means of which a member of the A. S. S. T. is able to increase his list of friends, and that is by making a greater effort to come in contact with other members of the Society, never losing an opportunity where a few are gathered together to be numbered among those present, by attending National Conventions, Sectional Meetings, and attending regularly your local Chapter Meetings brings you in contact with the best men in the nation and in your city, and the result of this personal contact will indeed be surprising to you.

As an example,—an individual in one of the western chapters became personally acquainted with the men of the chapter through his regular attendance at the Chapter meetings and when he needed an opportunity to show his ability and talent to another firm he had no difficulty in making a satisfactory advancement at a 100 percent increase in salary,—due to the acquaintanceships he had formed and the knowledge of his ability that had been gathered by those with whom he associated.

Another instance in which personal contact and the formation of friendships proved of great value was that of an executive who had become connected with a firm in unfortunate financial difficulties and it was necessary

for them to release him. He had been a regular attendant at meetings and consequently had built up quite an acquaintanceship When some of his friends found out that he was soon to be at liberty they immediately interested themselves in his behalf and within a period of one week he had been selected as works manager of a large western manufacturing firm at a salary of $7,000.00 a year, when previously he had been drawing but $3,500.00.

These are just instances of the value of friendships formed by attending local meetings and they are only indicative of the friendships that one is able to form by attending Sectional and National Meetings. Personal acquaintanceships and friends offer wonderful opportunities to all and if you do not embrace these opportunities as they are offered, you need have no one else to blame but yourself if when the time comes your friends prove not to be "stickers" but "sliders."

SLOGAN

H. ADDINGTON BRUCE, in the Associated Newspapers, writes interestingly and entertainingly on the subject, "Do It Better."

Of all slogans, the young man beginning in business will do well to make it his own, as none is of more importance to him than "Do It Better."

And how often it happens that a man having noticeably progressed through steadfast devotion to the principle summed up in a slogan finally reaches a point where he thinks he may safely spare himself the effort adhesion to it involves. He has arrived he tells himself and now can take things easy. But, he discovers, sooner or later, that to take things easy means to lose ground in a business sense because there are always speedy workers with whom the slogan "Do It Better," has an irresistible appeal.

This is the cause and explanation of many an unexpected collapse of industrial and commercial firms thought to be securely entrenched in the business world. It is the explanation too of frequent demotions of executives. One has only to use one's eyes to perceive that, to many men, the idea of "take it easy" has a stronger appeal than "Do It Better." Their thoughts and efforts are concentrated on almost anything except work improvement.

Naturally they are hopelessly handicapped in competition. They are out-distanced by men perhaps conspicuously their inferiors in point of inborn talent, but imbued with the "Do It Better "idea.

THE ART OF SELLING

IN AN address delivered by Dr. Frank Crane at the New York Life Insurance convention, at White Sulphur Springs, he brought out very forcibly those points which in his mind were paramount to the success of a salesman. As we are all salesmen, selling ourselves to our friends, colleagues, etc., some of Mr. Crane's thoughts will undoubtedly prove of value to our readers as well as to ourselves.

In laying down those points which he considers prerequisites we feel that he has struck the keynotes of the situation. His points are:

1. *Be Agreeable.*—If your voice is disagreeable and your manner of speech indistinct, see specialists. Don't get mad. I like you to be sunny, but I don't want you to get freckles.

2. *Know Your Goods.*—And when you tell me anything, talk plainly. Most salesmen lack imagination. They cannot conceive the extent of my ignorance.

3. *Don't Argue.*—When you argue with a man, you are trying to push

him. He may be weak and pretend to be convinced. Overnight he will change.

4. *Make It Plain.*—Get a grasp on the fellow you are talking with. Do not get out that little book that will only puzzle him. Answer his questions without looking at your books, charts, tables.

5. *Tell the Truth.*—By the law of average, honesty is the best policy and gives the greatest profits. If you are working for a concern where you cannot tell the truth, quit and go elsewhere.

6. *Remember Names and Faces.*—Don't call me Green when my name is Crane. I am sensitive about my name. Don't call me Mr. if my title is Doctor.

7. *Don't Be Egotistical.*—I am. You must not be. Don't show off. You came to sell me something, not to make a good personal impression. Magnify my ego, not yours.

8. *Think Success.*—Radiate prosperity. Do not mention calamities, dirges, funerals. Be a little Pollyanna.

9. *Be Human.*—If the company merely wanted to disseminate information, they would use a catalogue, not you.

ENGINEERS, SCIENTISTS AND EDITORS PLAN TO STANDARDIZE SYMBOLS AND ABBREVIATIONS

A RECENT conference held in New York city under the auspices of the American Engineering Standards committee revealed a sentiment among engineers, scientists, government officials, business paper editors and industrial executives, emphatically in favor of the unification of technical and scientific abbreviations and symbols.

It was agreed on all sides that the standardization of abbreviations and symbols would result in inestimable mental economies. The present situation with respect to the use of abbreviations and symbols in engineering, scientific, and other technical fields is comparable to a language which has degenerated into a multiplicity of dialects each of which has to be translated for the users of the others. Abbreviations and symbols constitute an ever growing and important part of the language of engineers, scientists, industrial editors, and other technical men. The use of one symbol or abbreviation for several different terms and the use of several different symbols or abbreviations for one meaning are, however, at present causing a great deal of confusion, misunderstanding, and, often, serious errors.

The conference was called upon requests from the American Institute of Electrical Engineers, the American Society of Mechanical Engineers, and the Association of Edison Illuminating Companies, to consider abbreviations and symbols, but after some discussion of the subject it was thought desirable to include as a part of the project, the graphical symbols which are used in engineering drawings, diagrams, and the like, for representing instruments and apparatus and components of them.

It was agreed that the co-operation of foreign standardizing bodies should be sought, in the development of the work. The importance of international uniformity in symbols is great on account of the international character of much engineering and scientific work, and the importance of reference books and periodicals in foreign languages.

The work will go forward under a committee organization developed in accordance with the rules and procedure of the American Engineering Standards committee.

SPRING SECTIONAL MEETING

THE board of directors of the American Society for Steel Treating have accepted the Lehigh Valley chapter's invitation to hold the spring sectional meeting in Bethlehem, Pa. The dates decided upon are Thursday and Friday, June 14 and 15, 1923.

The City of Bethlehem, in addition to being the center of a large industrial community, is ideally located for this purpose, it being 2½ hours ride from New York on either the Central Railroad of New Jersey or the Lehigh Valley railroad; 2½ hours ride from Harrisburg on the Philadelphia and Reading railroad; 1½ hours ride from Philadelphia on the Philadelphia and Reading railroad. Through trains on the Central Railroad of New Jersey from Scranton to Philadelphia pass through Bethlehem and all through trains on the Lehigh Valley railroad from Buffalo to New York pass through Bethlehem, which gives that city excellent train service, it being very accessible from all directions.

The program offered by the Lehigh Valley chapter members is as follows:

Thursday June 14, 1923

11:00 a. m. Registration.
12:30 p. m. Luncheon at Hotel Bethlehem.
2:00 p. m. Technical session at Hotel Bethlehem.
7:30 p. m. Dinner and entertainment at Hotel Bethlehem.

Friday June 15, 1923

9:30 a. m. Inspection trip through Bethlehem plants of the Bethlehem Steel Co.
1:00 p. m. Luncheon, Lehigh university.
2:30 p. m. Technical session, Lehigh university.

The Lehigh Valley chapter in addition to providing entertainment for their members, have arranged a program which all the visiting ladies will much appreciate. Their entertainment is scheduled as follows:

Thursday June 14, 1923

11:00 a. m. Registration, Hotel Bethlehem.
12:30 p. m. Luncheon with members at Hotel Bethlehem.
2:00 p. m. Auto trip (probably Delaware water gap).
7:30 p. m. Dinner and entertainment with members at Hotel Bethlehem.

Friday June 15, 1923

10:00 a. m. Sight seeing trip through historical places of interest adjacent to hotel.
1:00 p. m. Luncheon with members at Lehigh university.
2:30 p. m. Card party at Lehigh university in same building in which meeting is held.

The larger industrial institutions in this community which are represented and co-operate with the American Society for Steel Treating are, Bethlehem Steel Co., Bethlehem, Pa.; Bethlehem Foundry & Machine Co., Bethlehem, Pa.; Ingersoll-Rand Co., Phillipsburg, N. J., and Easton, Pa.; International Motor Co., Allentown, Pa., and Wm. Wharton Jr. Co., Easton, Pa.

It is impossible to arrange trips through all of the plants and it was decided that a sight seeing trip through the Bethlehem plant of the Bethlehem Steel Co. would be most interesting.

Two large educational institutions are covered by the field of the Lehigh Valley chapter, they being Lafayette college, located at Easton, Pa., and

Lehigh university, at Bethlehem, Pa. Lehigh university, through its president, Dr. C. F. Richards, is co-operating with the American Society for Steel Treating, and has given over the use of its dining hall and recreation building for the meetings, which will be held Friday. Lehigh university is particularly pleasing, especially at this time of the year, being located on the side of the mountain with its numerous buildings and well kept drives and campus.

A large, modern hotel has been opened in Bethlehem within the last year which can accommodate all who wish to attend the meetings. The Hotel Bethlehem is absolutely fireproof and its manager has offered the use of all of its facilities to the American Society for Steel Treating for their June meetings. The Lehigh Valley chapter feel that it would be better to have hotel reservations made through them rather than by direct communication with the Hotel Bethlehem, and it is requested that any one who desires to make reservations, should get in communication with G. C. Lilly, superintendent of the heat treatment department, Bethlehem Steel Co., Bethlehem, Pa., who will handle the matter.

The following men have given their consent to present papers at this meeting:

Dr. F. C. Langenberg, Watertown Arsenal.
V. Hybinette, British-American Nickel Co.
F. R. Palmer, Carpenter Steel Co.
B. F. Shepherd, Ingersoll-Rand Co.
R. H. Christ, Bethlehem Steel Co.

The subjects of these papers will be announced at a later date.

The entertainment committee, which consists of the following men;

W. R. Shimer, Chairman,
H. S. Brainerd,
A. Hummel,
F. P. Martin,
W. H. Laury,

have planned a good time for all and have guaranteed that all the members and their ladies will feel sorry that the sectional meeting was not a week long in place of only two days, and feel that in addition to the technical side that the social side will be well taken care of.

The meeting and inspection committee, of which Mr. Lilly is chairman, consists of the following members;

R. M. Bird,
F. V. Larkin,
R. H. Christ,
E. B. Shimer,
B. H. DeLong,

who have had the co-operation of the Lehigh university and are under obligation to the Bethlehem Steel Co. for their kindness in allowing an inspection trip which is scheduled for Friday morning, through the Bethlehem plant of that corporation.

It is hoped that all those who can possibly attend will be on hand in Bethlehem on June 14 and 15, as the Lehigh Valley chapter is composed of live wires and if their past is any criterion, the sectional meeting is sure to be a success in every way.

THE USE OF VARIOUS KINDS OF LIGHT IN METALLOGRAPHY

By Robert G. Guthrie

Abstract

This paper deals with a short discussion of the physics of light and a few of the important laws which govern the action and behavior of light and light waves.

After briefly discussing light the author turns to a discussion of the optics and mechanics of the metallurgical microscope as it is manufactured today. He discusses the various types of photographic plates which are available for photomicrographic work, indicating that the panchromatic plate gives the highest degree of satisfaction in making photomicrographs of opaque objects.

The use of ray filters and monochromatic light by the dispersion of white light into the different colors of the visible spectrum are reviewed. The use of polarized light in the photomicrography of opaque objects is discussed at some length and photomicrographs made by this method are included with this paper. Specimens of photomicrographs showing the magnifying power of the usual type metallographic camera are displayed. A photograph at 11,000 *diameters magnification is included.*

Introduction

LIGHT is an agent, the action of which on the retina of the eye, excites the sensation known as vision. Various hypotheses have been advanced to explain the origin and transmission of light, the most important being the emission of corpuscular theory, and the undulatory or wave theory. The emission theory assumes that luminous bodies emit in all directions, some substance, the molecules of which are propagated in lines at enormous velocity. This theory has long since been discarded, and the one accepted is the wave, or undulatory theory, which assumes that all bodies and all space is filled with an extremely subtle elastic medium called *ether*.

The luminosity of a body is due to an infinitely rapid motion (possibly vibratory) of its atoms, which, when communicated to the ether, are propagated in every direction as spherical waves. These light waves, however, do not vibrate in a plane parallel to the direction of propagation, but in a plane at right angles to it. An example that may illustrate this point is that of a water wave, which, although apparently moving in a given direction, vibrates in a plane at right angles to its direction of propagation. Another example is that of a caterpillar moving along in a straight line. In every homogeneous medium, the propogation of light is rectilinear. Light changes its direction when it meets an object which it cannot penetrate, or, when passing under certain conditions from a medium of a given density to one of a greater or less density.

Reflection and Refraction Phenomena

These phenomena are manifest by what is known as reflection and re-

A paper presented before the winter sectional meeting held in Chicago Feb. 8-9, 1923. The author, Robert G. Guthrie, is metallurgist with the Peoples Gas Light and Coke Co., Chicago.

fraction. An example of reflection which is well known, is the change of direction of the propagation of a pencil or beam of light by a mirror. There are two laws which govern the reflection of light, and radiant heat as well:

1. The angle of reflection is equal to the angle of incidence.
2. The incident and reflected ray are both in the same plane and this plane is perpendicular to the reflecting surface. The intensity of reflected light must always be less than the incident light due to the absorption of a part of the incident light by the reflecting body.

The phenomenon of refraction is seen every day by all of us, as that peculiar form of distorted vision that we see when looking at an object through a glass filled with water, or through a bubble or imperfection in a window pane. When a beam of light passes obliquely from one medium to another of different density, it suffers refraction. All of this beam, however, does not enter the second medium, but a portion of it is reflected; also, all of the beam which enters the second medium is not refracted, but a part is absorbed and appears as heat. The portion that is reflected is subject to definite laws. In isotropic bodies, such as air, liquids, and ordinary glass the ray is singly refracted, and two laws known as the Descartes laws for single refraction are:

1. Whatever the obliquity of the incident ray, the ratio which the sine of the incident angle bears to the sine of the refraction angle, is constant for the same two media, and the same colored light, but varies with different media.
2. The incident and refracted rays are in the same plane which is perpendicular to the surface separating the two media.

Refractive Index

The index of refraction or refractive index of the second medium with respect to the first, is the ratio between the sines of the incident and refracted angles. This may be expressed as follows:

Let A = the refractive index
B = the angle of incidence
C = the angle of refraction
Then, Sin B = A Sin C

The refractive index varies with the media, as from air to glass it is 3/2 and from air to water it is 4/3; in other words, the refractive index of water is 1.333 and for glass 1.500. If the refractive index of a substance is given without qualification, such as just the figure 1.333 for water, it is understood that the light is passing from air into the substance. If, however, the light is passing from water to air, it follows the same course but in a contrary direction, with the consequent result that the index of refraction is reversed and the figure 4/3 from air to water becomes 3/4 from water to air.

It is apparent that the index of refraction varies with different media and the following figures for different substances will make this clear. Remember, however, that the light is passing from the air into these media. Ethyl ether 1.36, ethyl alcohol 1.37, turpentine 1.47, crown glass 1.53, flint glass 1.63, diamond 2.75. A point which is now obvious is that optical density is not the same as ordinary density, inasmuch as the index of refraction of

ethyl ether, ethyl alcohol, turpentine, etc., is larger than the index of refraction for water, but they are all lighter than water. This optical density gives rise to another law as follows:

> Light passing from a less dense medium to one of greater density obliquely to the surface separating the two, is bent toward the perpendicular to that surface, and conversely, in passing from a more dense medium to a less dense medium, it is bent away from the perpendicular.

The question may now arise as to why a beam oblique to a surface is bent or refracted, whereas one perpendicular to that surface is not, and the explanation is found in the velocity of light. The velocity of light is approximately 3 x 10^{10} centimeters per second, or 186,000 miles per second. When a beam of light passes from one medium to another, the velocity in the first medium is to that in the second inversely as the refractive indices of the media, which means that the velocity of light in water is three-fourths that of its velocity in air, and the velocity of light in the glass, having a refractive index of 1.5 is 2/3 of its velocity in air.

A beam of light passing from air to water perpendicular to the surface of water, is not refracted, but is equally retarded along its entire length for the reason of the fact that light travels only three-fourths as fast in water. Also the angle of incidence of the beam is 90 degrees, but if the beam makes an angle less than 90 degrees with the surface of the water, the wave front which is always perpendicular to the direction of the propagation must strike the surface on one side before it strikes on the corresponding point directly opposite. As an example, incline a water glass slightly with the top of a table, and it will be seen that the table and the glass touch only on the edge. As the velocity of the entire wave front is constant, the point first striking the medium which retards its velocity by one-fourth will have traveled into the water before the point which was opposite in air has reached the surface, with the result that there will be a swinging of the entire beam toward the common perpendicular, and inasmuch as the wave front is always perpendicular to the beam, there will be a change of direction.

The numerical value of the refractive index is always the ratio of the velocity of light in the first medium to its velocity in the second, and when light passes into a medium of greater density, the index is greater than one and the ray is bent toward the perpendicular and conversely when light passes into a medium of less density, the index is less than one and the beam is bent away from the perpendicular. A beam of light, therefore, can always pass from a less dense medium to one of greater density as it is bent toward the perpendicular, but a ray cannot always pass from a dense into a less dense medium for the reason that if the ray is bent away from the perpendicular more than 90 degrees it would not emerge. A beam of light cannot pass from water into air if it makes a greater angle with the perpendicular than 48 degrees 35 minutes. This is known as the critical angle and beams that make greater incident angles than the critical angle are *totally reflected.*

This principle of refraction is responsible for the various effects produced by lenses. If a piece of glass, say 3 inches in diameter and 1 inch thick is placed perpendicular to a beam of light, the light in passing will suffer no refraction, but if one of the surfaces is curved outward toward the beam, the effect will be analogous to the oblique beam striking the plane surface of the water just mentioned, but in this case, the surface is oblique

to the wave front. The effect produced will be to refract or bend the wave front toward the common perpendicular.

The foregoing is given merely to explain a few terms such as reflection, refraction, refractive indices, wave front, etc., and to give a brief account of the phenomena which make lenses possible, and which in turn, make possible our present day microscopes, field glasses, telescopes, cameras, motion picture and stereopticon projectors, and ordinary eye-glasses.

The Metallurgical Microscope

The metallurgical microscope is dependent entirely upon light for its existence as a useful mechanism. The lens systems are complex, and as you have seen by the short description just given, the nature of light and its application bids fair to be the most complex element entering into its use, however, thanks to the optician and physicist, the troublesome details of the lens combinations have been attended to. Their proper spacing, mounting and positions have been determined when the instruments were made and with proper care and attention to illumination and photographic materials and equipment, proper and satisfactory photographs may be obtained. It is the writer's opinion that any specimen worth photographing is worthy of the best photomicrograph that can be taken of it. If this rule were followed we should have fewer poor and unintelligible photomicrographs.

The illustrations in this paper are not in any sense of the word examples of perfect photomicrographs, but they represent three points which are brought out in this discussion. These points are as follows:

1. Kind of light used.
2. Polarized light, plain polarized and analyzed.
3. Magnification, normal and extreme.

By the kind of light used is meant white light, which is a compilation of all the colors known to us in the visible spectrum. Monochromatic light is a light of a definite wave length and is consequently of definite color, or semimonochromatic light, is a light of a narrow range of wave lengths, and consequently apparently one color. The nature of white light is such that it is composed of various colored lights of wave lengths within the visible spectrum, between 4000 and 7000 Angstrom units. A wave of the darkest violet that can be seen will be about 4000 Angstrom units in length. The Angstrom unit is one ten-millionth of a millimeter, and a wave of the darkest red that can be seen is about 7000 Angstrom units. We can make photographs with any of the various wave lengths within the visible spectrum, as well as some of the shorter wave lengths above 4000 Angstrom units, which affect the photographic plate, but which are not visible to the eye. Examples of these are the ultra-violet and violet, and are sometimes referred to as the chemical rays.

Photographic Plates

The photographic plates such as are used for photomicrography may be either the ordinary gelatine plates, the orthochromatic, the isochromatic or the panchromatic. In the matter of the selection of plates it is well to remember that the ordinary gelatine plates are sensitive toward the red end of the spectrum as far as the green, whereas the orthochromatic plates are sensitive to the orange and panchromatic plates are sensitive to the infra red. This latter class of plate in the writer's estimation is the ideal plate

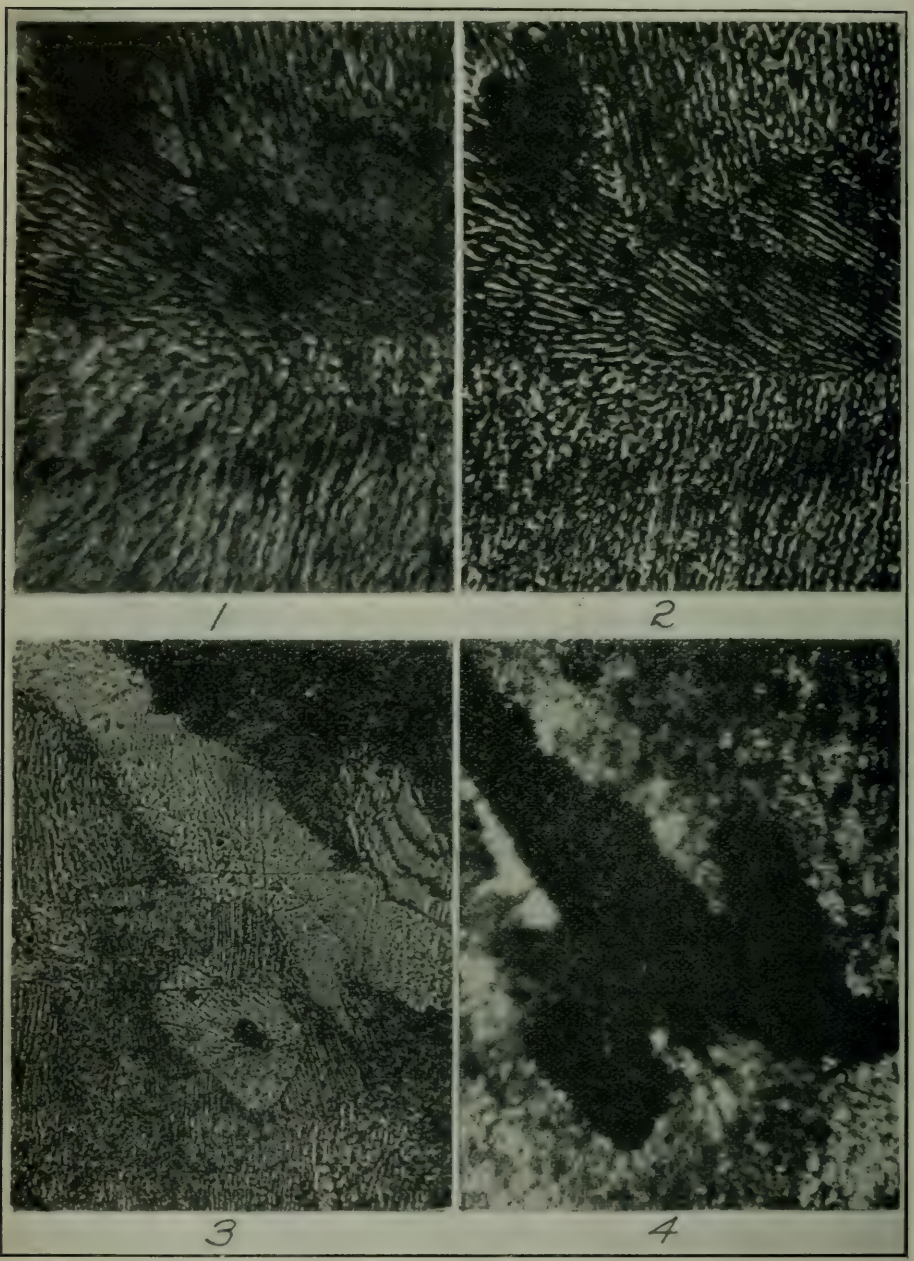


Fig. 1—Photomicrograph Of Lamellar Pearlite Taken Without The Use Of A Ray Filter. x 2000. It Will Be Seen That The Photograph Lacks Contrast And Has A Blurred Effect Due To The Use of White Light At High Magnification. Fig. 2—Same Section As Fig. 1 With The Same Equipment But In This Case A Light With A Spectral Transmission Of 4600-6000 A. u. Was Used. Fig. 3—Photomicrograph Made By Using The Arrangement Of Polarizer And Analyzer As Shown In Fig. 7. Fig. 4—Photomicrograph Made By Rotating The Analyzer Through 90 Degrees, Thus Reversing The Colors Of The Constituents As When Oblique Light Is Used. These Photomicrographs Were Taken At x 1000.

to be used where the best results are desired. These plates must be handled and developed in a room totally dark, or by the light of a special lamp recommended by the manufacturer of the plates.

Ray Filters

Another important point that must be taken into account if the best results are to be secured is that it is necessary to have a set of ray filters furnished or recommended by the manufacturer of the plates. These ray filters consist of gelatine films stained by various dyes cemented between glass plates, and although these filters do not produce perfectly monochromatic light, they produce light of various dominant wave lengths, with the result that the microscopist has a larger choice of wave lengths and colors from which to work. Certain combinations of these filters give practically monochromatic light. There is, however, another way to obtain monochromatic light which is no doubt superior to all others, and that is by separating a beam of white light into all its different colors by the use of suitable prisms. It is necessary that each band of color be wide enough to be used for illumination. However, for all practical purposes of photomicroscopy, panchromatic plates with a set of suitable filters will give excellent results. Filters of colored glass as supplied with some instruments are generally suitable for ordinary plates but not at all suitable for the panchromatics.

The reasons for the use of light of different colors, or different wave lengths, are several, among which is to obtain greater contrast between the various constituents. It is ordinarily not necessary to employ any but white light with magnifications below 100 diameters, but above this point they become necessary, and at very high magnifications of 2000, 3000, 4000 diameters, and upwards, their use becomes imperative. An example of this is shown in Figs. 1 and 2. Fig. 1 is a photomicrograph of lamellar pearlite taken at 2000 diameters without the use of a filter, and it will be seen that the photograph not only lacks in contrast necessary to bring out the detail, but gives the blurred effect which is another consequence of using white light at high magnifications. Compare Fig. 1 with Fig. 2, which is the same section photographed with the same equipment but in this instance a light was used having a spectral transmission of 4600 to 6000 Angstrom units and, therefore, of a green color. Figs. 5 to 11, dealing with increased magnification, were all taken of lamellar pearlite, with light of the same wave length as was used in the case of Fig. 2.

Resolving Power of Objectives

The relation of the wave length of light to the resolving power of the objectives is a most important issue. The resolving power of an objective is frequently referred to in lines per inch, that is, an objective is frequently spoken of as being capable of resolving 25,000 lines per inch. The distance between two lines which can just be distinguished (or resolved) by the objective, is equal to one-half of the wave length of light, divided by the numerical aperture of the objective. The formula expressing this is:

$$D = \tfrac{1}{2} \frac{Wl}{N\,A}$$

Where D = the distance
Wl = the wave length of light
N. A. = the numerical aperture

It will immediately be seen that the shorter the wave length of light, the

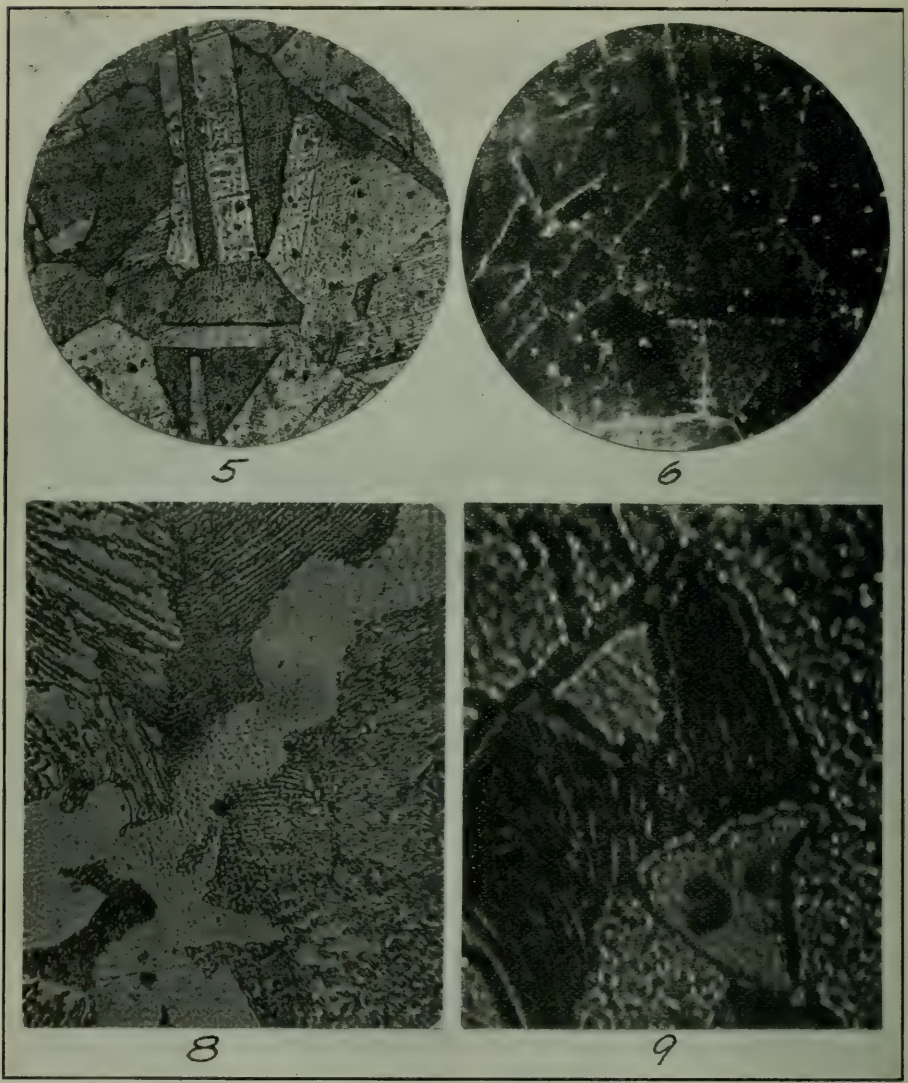


Fig. 5—Photomicrograph Made Using The Arrangement Of Polarizer And Analyzer As Shown In Fig. 7. Fig. 6—Photomicrograph of Same Section When The Analyzer Is Rotated 90 Degrees. It Will Be Noted That The Colors Are Apparently Reversed As When Oblique Light Is Used. These Photomicrographs Are Magnified x 300. Fig. 8—Lamellar Pearlite Photographed At A Magnification Of x 1200. Fig. 9—Low Carbon Steel Showing Ferrite, Ferrite Grain Boundies, And A Central Area of Lamellar Pearlite. x 2300. These Last Two Pictures Were Taken With Vertical Illumination.

greater the resolving power. Very interesting and useful figures may be compiled from the above formula. For example, the highest numerical aperture obtainable is about 1.40, and using a wave length of light of 6000 Angstrom units the lines resolved per lineal inch will be, roughly, 125,000, whereas with a wave length of 4000 Angstrom units the lines resolved per lineal inch would be nearer 200,000. This, however, is not possible as the volume and intensity of light would be insufficient in the first place, and in the sec-

ond place, it would not be visible enough to focus. A point to remember in connection with the use of filters is that the final focusing must be done with the filter in place, as poor results will be obtained if the focusing is done with white light and the filter placed in the beam later.

Polarized Light

The attempt to use polarized light for the examination of opaque objects was made in the hope that it might prove of value in some classes of work. The writer admits the attempt has not been very complete as yet but will explain what is meant by polarized light.

In the first part of this paper, we spoke of refraction as single refraction. Now, if a beam of light is passed through a crystal of Iceland spar (a transparent calcite) or a tourmaline crystal, in the proper manner, the ray breaks up into two rays of equal intensity; one known as the ordinary ray, and the other, the extraordinary ray. Practically speaking, in the polarizers

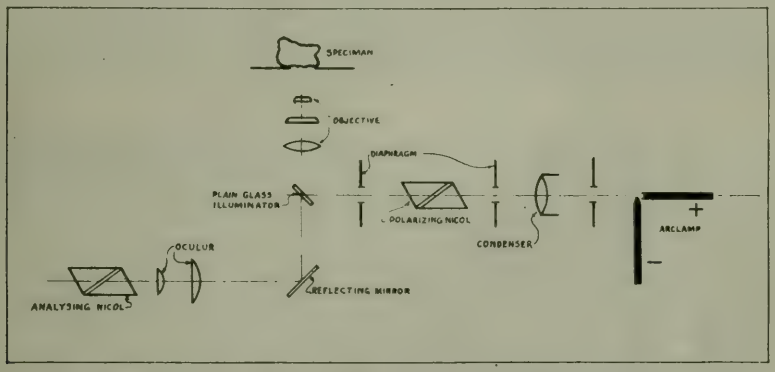


Fig. 7—Diagrammatic Sketch Of The Usual Inverted Type Metallographic Microscope With The Polarizer And Analyzer In Place.

used, the ordinary ray is refracted through the sides of the crystal and absorbed while the extraordinary ray passes on through and is said to be a ray of plain polarized light. It is an essential of such a polarizer that another crystal is used to analyze the plain polarized beam.

Before going further, it might be well to explain more fully what is meant by a polarized beam and we will use an illustration given in an elementary textbook by Henderson and Woodhull.

By fastening a cord at one end, and holding the other in the hand, the cord is made to ripple in all possible planes, it will very crudely represent an incident ray of light. If this cord in place of being fastened at one end is passed through two gratings whose openings are rectangular in shape, and these gratings are placed some distance apart, a fair representation of a polarizer and analyzer is seen. When the direction of both these slits is placed vertical, and the cord made to ripple up and down, vibrations pass along its full length. If both gratings are revolved through 90 degrees and the cord made to ripple horizontally, the cord will also vibrate throughout its length, but if the grating furtherest from the hand is turned through 90 degrees to the vertical position and the other left horizontal and the cord rippled horizontally, it will be seen that the end furthest away from the

hand, transmits no vibrations, therefore, remaining stationary. Something similar to this appears to happen to a beam of light passing through a crystal of Iceland spar.

A very convenient and logical way to imagine natural light or incident light as opposed to polarized light is to assume that the ray of incident light is plain polarized and subject to sudden and irregular changes. If these changes take place very slowly the two rays, the ordinary and extraordinary, would not be of equal intensity, but if these changes take place more rapidly than the eye can follow them, we would have what is apparently two images of equal intensity at any given time interval. Assuming that the eye can detect alternations at time intervals of one-fiftieth of a second or faster and these changes occur within such a time factor or time cycle, then we would see what we might term alternating or circular light by a varying intensity of the ordinary and extraordinary ray. The question will now naturally arise as to why it is necessary to use a calcite rhombohedron such as a crystal of Iceland spar.

If the incident beam is presumed to be in reality a plain polarized beam, the answer according to the present line of reasoning would be that the ordinary ray is made to refract in such a way as to be absorbed before it passes out of the end of the polarizer and in so separating these rays and eliminating one we have in effect eliminated only one time-phase of the original beam which allows the extraordinary ray emerging from the polarizer to vibrate in one direction for any given time interval and this direction being only relative to our purely imperialistic standard for direction may be changed by revolving the polarizer through any angle about its own axis.

The great obstacle in preventing the human mind from viewing natural phenomena as they really are, is not the fact that the eye cannot change quickly enough to follow the change in time-phase or alternation of a beam of light, if such is the case, but rather that the mind itself cannot conceive very much that does not lie close to its own set values of things which we call standards. These standards are probably not even close approximations to absolute conditions of various phenomena, but are only relative. It is a fair question then to ask what they are relative to, and the logical answer seems to be that they are more often relative to a given and somewhat limited set of present mental conceptions than to any actual true and absolute values of any given phenomena for which a given value or standard is set by a human mind.

Arrangement of Apparatus for Making Photomicrographs With Polarized Light

Fig. 7 shows a diagrammatic sketch of the usual inverted type metallurgical microscopic camera with the polarizer and analyzer in place. When these are so arranged that their axes are parallel, the ray of light passes through, giving apparently the same image as when a beam of incident light is used.

Figs. 3 and 5 show photomicrographs made using this arrangement of polarizer and analyzer. By rotating the analyzer through 90 degrees, the colors are apparently reversed, as when oblique light is used. Figs. 4 and 6 show photomicrographs of sections corresponding to Figs. 3 and 5 respectively when the analyzer is rotated 90 degrees. These two photomicrographs were taken at 1000 and 300 diameters magnification, respectively. With an oil immersion objective it would be impossible to get a photomicrograph at 1000 diameters magnification with oblique illumination by the present ordinary methods.

Theoretically, if the two crystals are parallel, the beam of polarized light

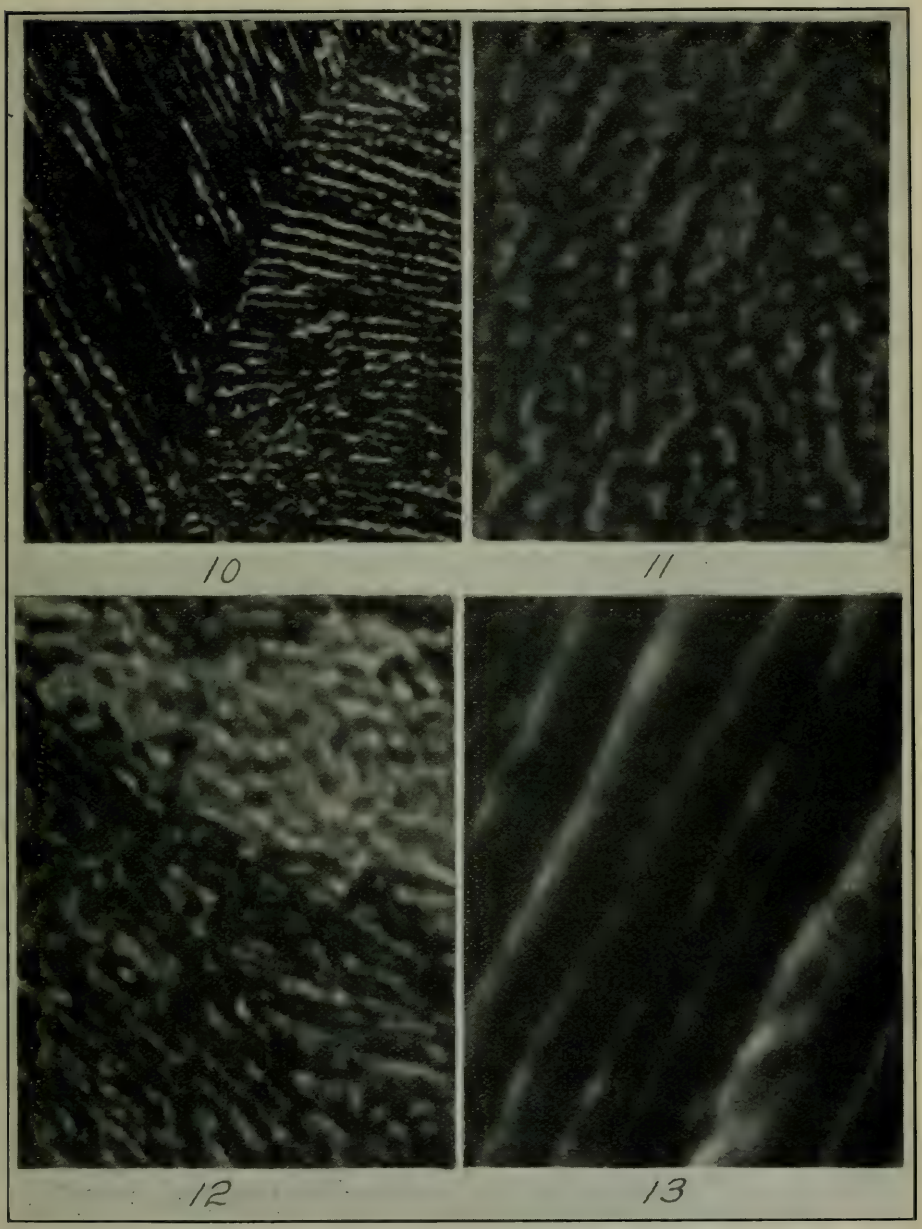


Fig. 10—Lamellar Pearlite At A Magnification Of x 3000. Fig. 11—Lamellar Pearlite At A Magnification Of x 5000. Fig. 12—Lamellar Pearlite At A Magnification Of x 5500. Fig. 13—Lamellar Pearlite At A Magnification Of x 11,000.

passes through to the eye unchanged, but when the analyzer is rotated through 90 degrees, the luminosity of the field decreases until at just 90 degrees it is entirely dark; no light being transmitted by the analyzer. This condition occurs from destructive interference.

(Continued on Page 757)

SELECTION OF ELECTRIC FURNACES FOR STEEL TREATING

By C. L. Ipsen

Abstract

This paper points out the fact that the electric heat treating resistor-type furnaces are coming into more universal industrial use. A few years ago the electric furnace was considered a laboratory device and not applicable to commercial use due to the high cost of electrical current and frequent breakdowns.

With improved design and an increased cost of gaseous, liquid and solid fuels the electric furnace is coming into use more and more. Its automatic control and its favorable atmospheric conditions surrounding the furnace and its cleanliness makes it an apparatus suitable for installation in locations in a shop other than the heat treating department. It can be placed in the line of production thus eliminating much handling of material.

A FEW years ago the electric furnace was generally considered as nothing more than a laboratory device, used in the laboratory because of the accurate results obtainable but shunned as a production furnace because of its unreliability. Furthermore, its use in production was not seriously considered because it was assumed that the high cost of the heat unit derived from electric energy would make the cost of heat treating prohibitive.

Design of Electric Furnaces Much Improved

By degrees electric furnace designs were improved and the troublesome features of the laboratory furnace construction were eliminated. Thus, for the past two or three years electric furnaces have been available that are fully capable of withstanding the rigors of large scale production rather better than their fuel fired brethren.

Perfection of design, however, answered only one of the objections. It still remained to prove or disprove the theory of high operating costs. The actual operation of only a few furnaces was required to show the fallacy of putting too much emphasis on British thermal units. There proved to be other considerations such as improved working conditions, reduced labor, improved quality of product, lower rejections, and lowered cost of subsequent operations that far outweighed the difference in British thermal unit cost between fuel and electricity in heat treating. So pronounced was the success of these first production furnaces that in an extremely short time the electric furnace has established itself as the standard where high-grade steel treating is required.

The electric furnace is now available in almost every form to suit the varied requirements of the steel treating field. The development of the many types has been greatly aided by the fact that most of the fuel-fired furnace types readily lent themselves to electrification. One feature of the electric furnace that distinguishes it from the fuel-fired furnace is that the restriction on its proper location in the line of production has been removed. It is not necessary with the electric furnace to restrict it to a furnace room

A paper presented before the Detroit convention of the society, October 2-7, 1922. The author, C. L. Ipsen, is designing engineer, industrial heating department, General Electric Co., Schenectady, N. Y.

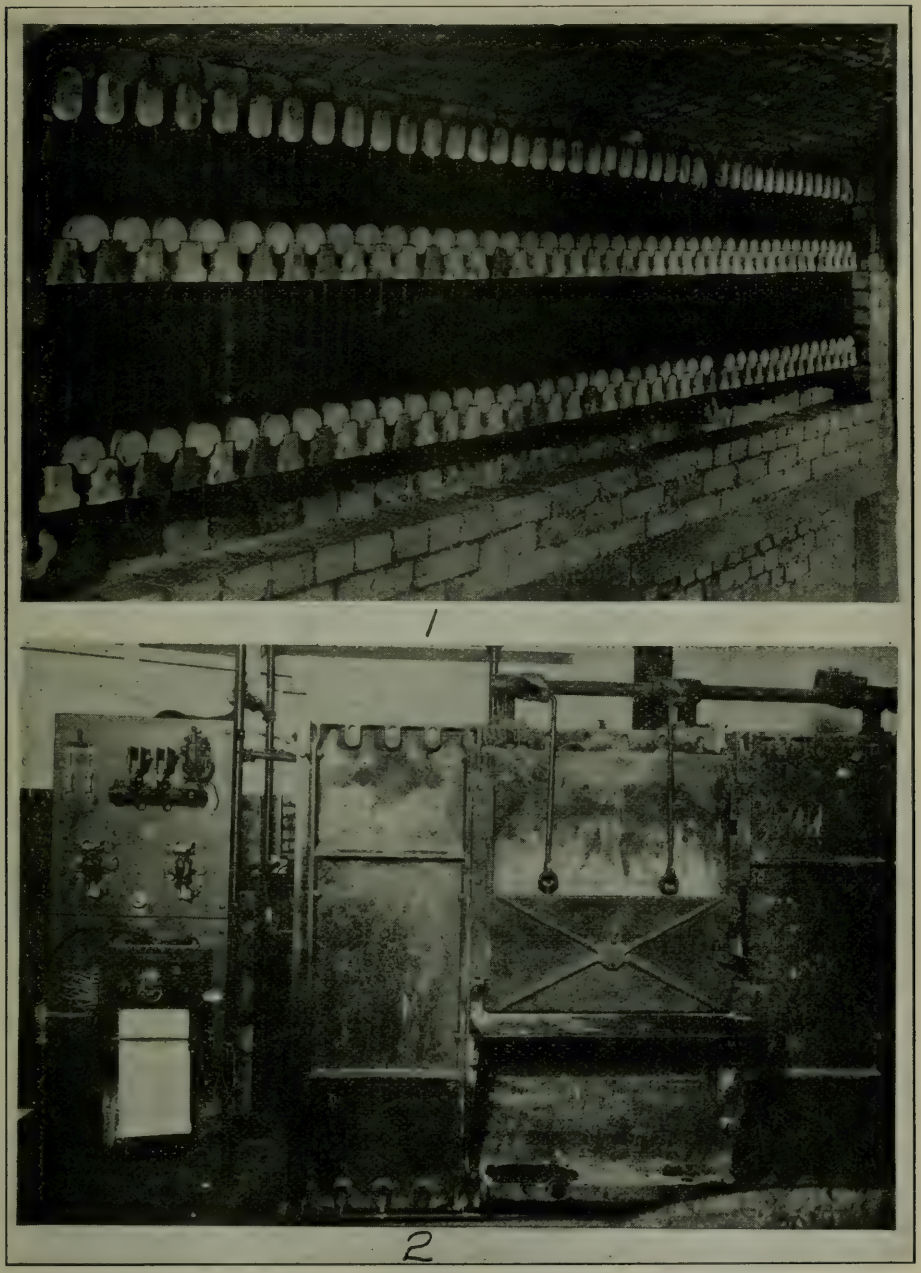


Fig. 1—Arrangement of Electric Heating Units on Side Wall of Car Type Furnace. Fig. 2—Electric Resistance Furnace with Panel and Instrument for Automatic Temperature Control.

apart from the manufacturing space on account of its noise, obnoxious fumes and intense waste heat, but it can be so located as best to fulfill its mission as a link in the manufacturing chain. Thus, what was once classified as one of the intangible advantages of the electric furnace, its absence of noise.

fumes and waste heat have become one of its chief advantages from the standpoint of actual savings. This feature has opened up for it a large field for relatively small electric furnaces of the automatic or semiautomatic type placed in the machine shop in the path of production.

Good Atmospheric Conditions Surrounding Electric Furnaces

Comparative tests made in a large plant illustrate this feature. On two furnaces of similar construction—one electric and one fuel-fired—tests were taken simultaneously of the atmospheric conditions surrounding the furnaces, as follows:

Electric Furnace—	
Temperature	79 degrees Fahr.
CO_2	4 per cent
Humidity	60 per cent
Fuel-Fired Furnace—	
Temperature	121 degrees Fahr.
CO_2	7 per cent
Humidity	23 per cent

It is estimated that a man's vitality after four hours' work in the atmosphere surrounding the fuel furnace would equal that of the man working in the atmosphere surrounding the electric for eight hours. It also shows vividly the reason for restricting the fuel furnace to the furnace room.

The many types of electric furnaces available bring to the mind of the prospective purchaser the question of selection, and it is a question that deserves more careful thought and study than is often given. A furnace not suited to the parts being heat treated or to the shop production may result in serious losses.

Many do not appreciate that a furnace must be designed with as much care as a motor or a machine tool, and in as great variety. It has been assumed too often in the past that a furnace was simply a pile of brick with a hole for a burner. It is not within the province of this paper to enter into a discussion of the many factors that surround the selection of electric furnaces for the great variety of steel treating requirements—each application would be worthy of a paper in itself—but rather to indicate briefly what furnaces have been installed to meet certain specific requirements.

Furnaces Automatically Controlled

The furnaces under discussion are of the direct-heat or open-resistor type. These furnaces are heated by heavy nickel chromium ribbon formed in loops and supported on the interior surface of the furnace in such a manner that the heat is radiated directly to the charge. This construction is clearly illustrated in Fig. 1. The temperature of the furnace is automatically maintained at a constant value by a temperature controlling instrument, which operating through suitable contactors in the main circuit throws the current on and off the resistors. By means of this special temperature control a maximum temperature variation of plus or minus five degrees Fahr. can be maintained.

One requirement met in almost every shop is for a furnace to heat tools and dies. Fig. 2 illustrates one of the first furnaces of direct-heat type, placed in commercial operation for this class of work. The principal output of the furnace is large complicated dies used for making field and armature punchings. This furnace since it was electrified (it was previously a fuel-fired furance) has been in continuous operation for three years without any repair to its heating equipment, nor is there any evidence of its deterioration.

The current is thrown on at 4 a. m. and off at 4 p. m. automatically by means of a time clock. The heat treater using this furnace, recently stated that this furnace has been up to temperature and ready for use every morning without a single exception for three years. This illustrates the dependability and convenience of furnaces of this type.

Fig. 3 shows a furnace designed for a similar purpose but of a more

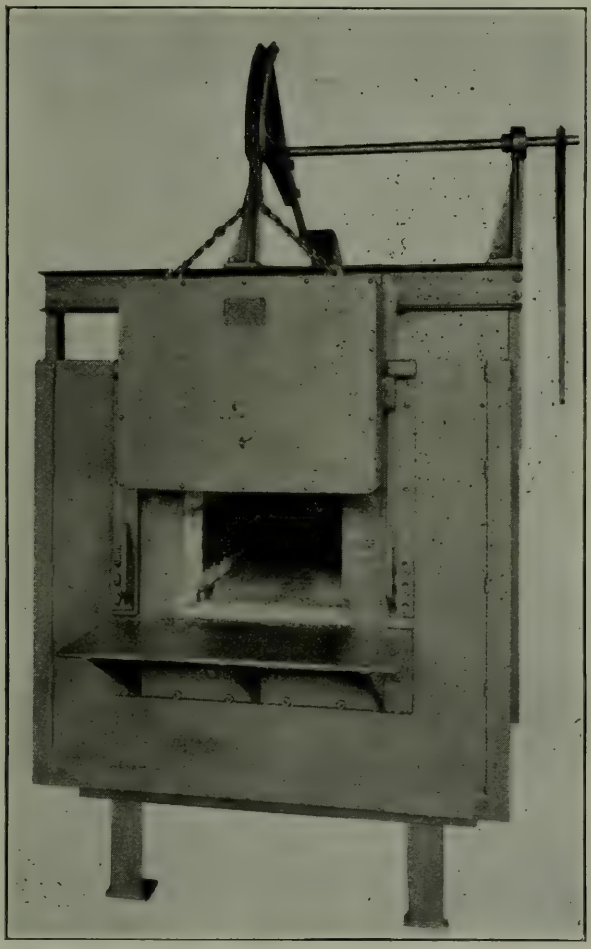


Fig. 3—Box Type Electric Resistance Furnace. Inside Dimensions 18" wide, 36" long and 15" high. 27 KW, 110-220 Volts.

modern type. A hearth of highly refractory metal is used and the resistors are so installed as to reflect a portion of their heat to the bottom of this hearth.

Where it is desired to heat treat parts too large and bulky to be placed in a box type of furnace, the car bottom furnace may be used. Fig. 4 shows a furnace used for annealing sheet steel punchings. A charge of eight to 10 tons is annealed to a temperature of 850 degrees Cent. in 14 hours. The picture shows an annealing cover which was provided to guard against the

possible oxidation of the punchings. After a few runs the use of cover was discontinued, as it was found that the amount of oxidation in the open furnace was so slight as not to be objectionable. This furnace is so designed as to complete its annealing cycle at night, thus obtaining the benefit of low power rate offered by many of the control stations for off-peak power.

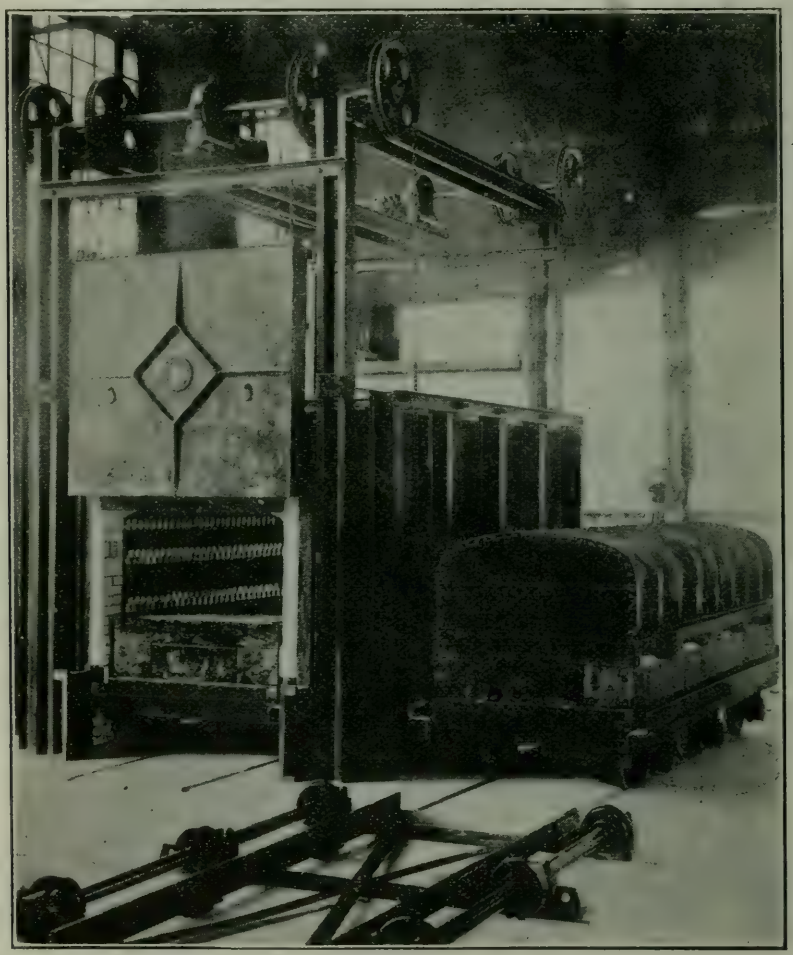


Fig. 4—Car Type Electric Furnace for Annealing Transformer Laminations in Containers.

Fig. 5 shows another car bottom furnace used for annealing or ageing large gray iron castings. A 50-ton charge is shown on the car. It has been found that a low temperature anneal (about 550 degrees Cent.) is sufficient to relieve the strains and give the castings a permanent set. On account of the uniformity of temperature distribution and the close temperature control of the electric furnace, it has been found ideally suited for this work.

A furnace of the compensating type for annealing cast iron is shown in Fig. 6. The furnace is five car lengths long and two wide. The heating chamber is equal in length to one car and is located at the center of the

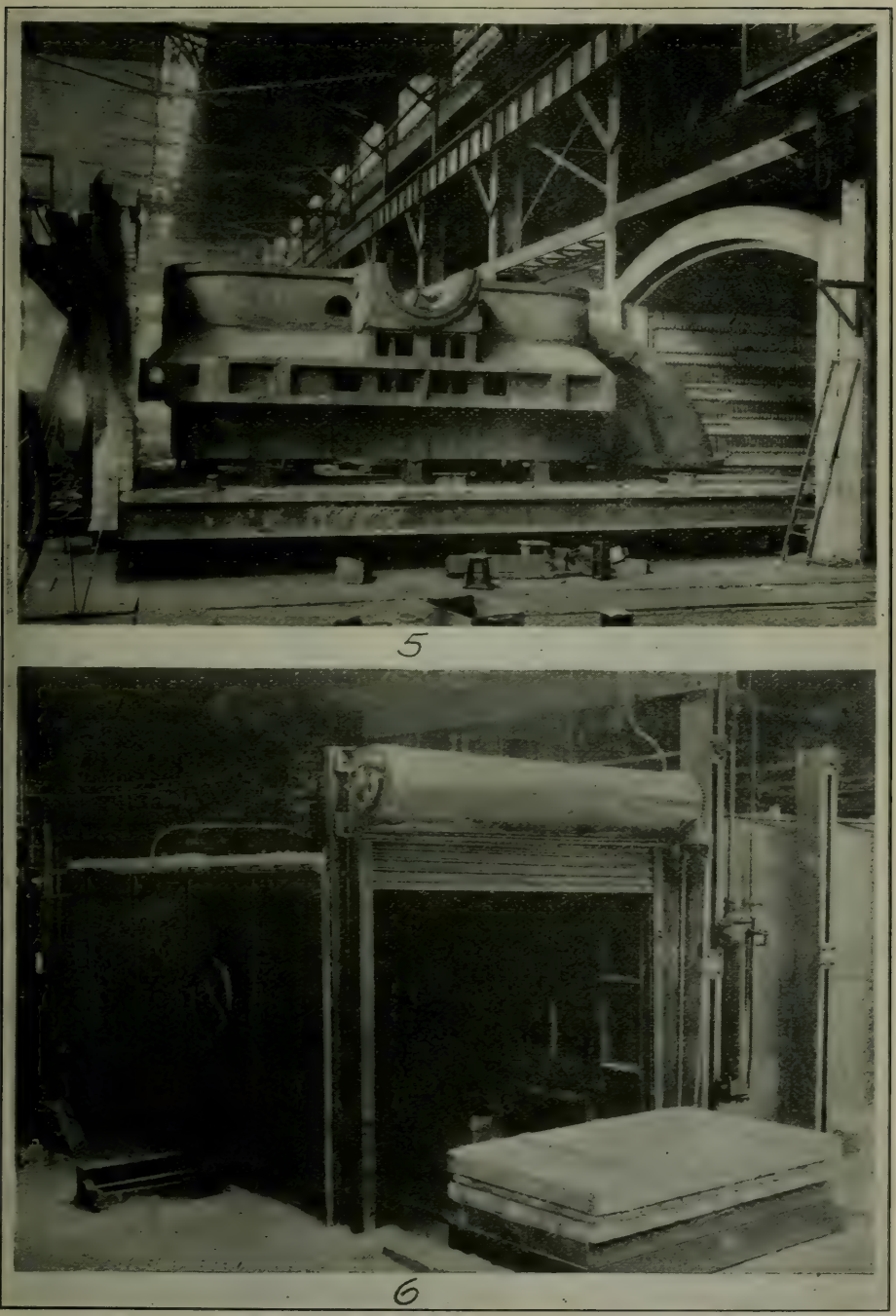


Fig. 5—Electric Heat Treating Furnace equipped with Automatic Temperature Control. Dimensions of Heating Chambers 15′-10″ wide 27′-7″ long and 8′-7″ high. Maximum Operating Temperature 1000° Fahr. 620 KW, 550 Volts, 3 Phase. Fig. 6—Car Type Compensating Electrically Heated Annealing Furnace. Heating Chamber 3′-10″ wide, 5′-6″ long and 3′ high. Connected Load 180 KW—Operating Temperature 1450° Fahr.

furnace. With the two trains of cars working in opposite directions, the car emerging from the heating chamber thus gives up its heat to the incoming cars. The castings in this manner derive a large part of their heat from the outgoing charge and reduce materially the current consumption.

A furnace which is well adapted to the heating of a great variety of parts is shown in section in Fig. 7. The hearth rotates, carrying the work around from the charging to the discharging doors. Since these doors are located side by side, one attendant can readily charge and quench the parts.

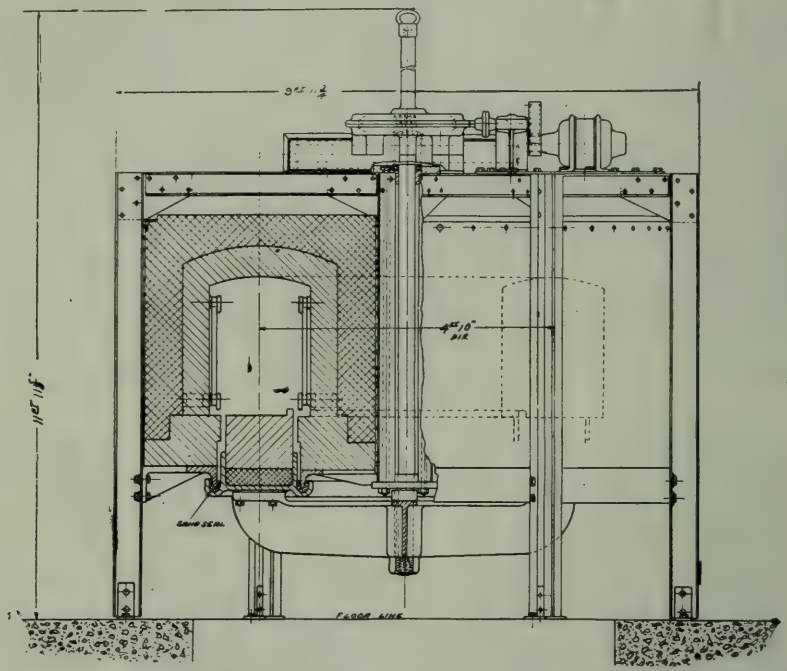


Fig. 7—Outline of Electric Resistance Heat Treating Furnace with Suspended Hearth, Revolvable about the Vertical Axis.

The furnace is well suited to the heat treatment of small parts such as rollers, set screws, etc., placed in containers, since the container can be refilled and returned to the furnace with only a small loss of heat. It is also convenient for heating small gears.

Accuracy of Control Obtained in Electric Furnaces

A good idea of the accuracy of heating can be obtained from a study of the heating curve (Fig. 8) of a gear as it is carried through the furnace. The solid line is the temperature of a couple imbedded in the hub of the gear and the dotted line shows the temperature at a point about six inches above the gear.

The actual operation of several furnaces of this type has resulted in large savings due to the reduction in scaling and warping. Savings in subsequent operations alone have saved two or three times the total cost of electricity. One user of this type of furnace was able to effect a saving of 2½ cents per part on heat treating labor alone, while the total cost of

electricity for heating the part was less than 2 cents. These facts are given to show how the actual operation of furnaces has completely disproved the theory of high operating costs of electric furnaces.

A large furnace (Fig. 9) of this type has been in operation for over a year for heating such parts as front axles, crankshafts, etc. This furnace

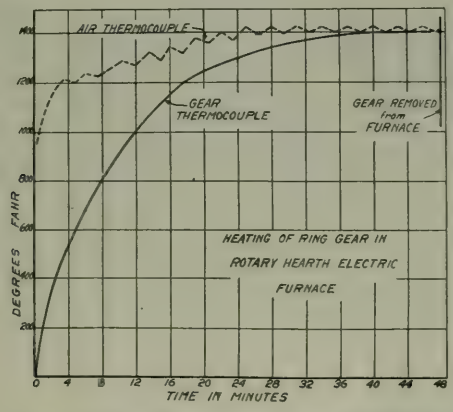

AIR THERMOCOUPLE
GEAR THERMOCOUPLE
GEAR REMOVED from FURNACE
HEATING OF RING GEAR IN ROTARY HEARTH ELECTRIC FURNACE
DEGREES F'AHR
TIME IN MINUTES
0 4 8 12 16 20 24 28 32 36 40 44 48

Fig. 8—Time-Temperature Curve of Ring—Gear Heat Treated in a Rotary Hearth Electric Furnace. The Solid Line shows the Temperature of the Gear with Thermocouple in Contact with it. The Broken Line shows the Temperature of the Furnace When a Thermocouple was placed a few inches from the Gear.

has a capacity of approximately 3000 pounds of steel per hour. It is frequently used at night for carbonizing, the entire hearth being filled with carbonizing pots.

Pusher Type Furnaces Are Adaptable

In Fig. 10 is shown a furnace of the pusher type for heat treating connecting rods. The heating units are of the ribbon resistor type and are supported in a horizontal position above the heating chamber. The parts are pushed through the furnace on a metallic hearth and are automatically dropped into the quenching bath. A conveyor carries them from the quenching bath to the drawing furnace. Furnaces of this type are particularly suited to the continuous heating of similar parts of such a shape that they can be pushed through the furnace without the use of containers.

Where parts are so shaped as to make the pusher type of furnace impracticable, other types of tunnel furnaces are available. In one type the parts are carried through the furnace by means of a walking beam fitted with prongs that project up through a slot in the hearth and step the parts along. In another type of tunnel furnace the parts being heated are carried through the furnace on metal rollers spaced at frequent intervals and slowly rotated.

Tunnel furnaces of these types are well adapted to installation in the line of production in the machine shop. The saving in handling charges alone when so installed will in many cases more than cover the total cost of electricity. The automatic control of temperature and of the time that parts are exposed to the heat gives a uniformity of quality and hardness that results in further savings in subsequent machining operations and in rejections.

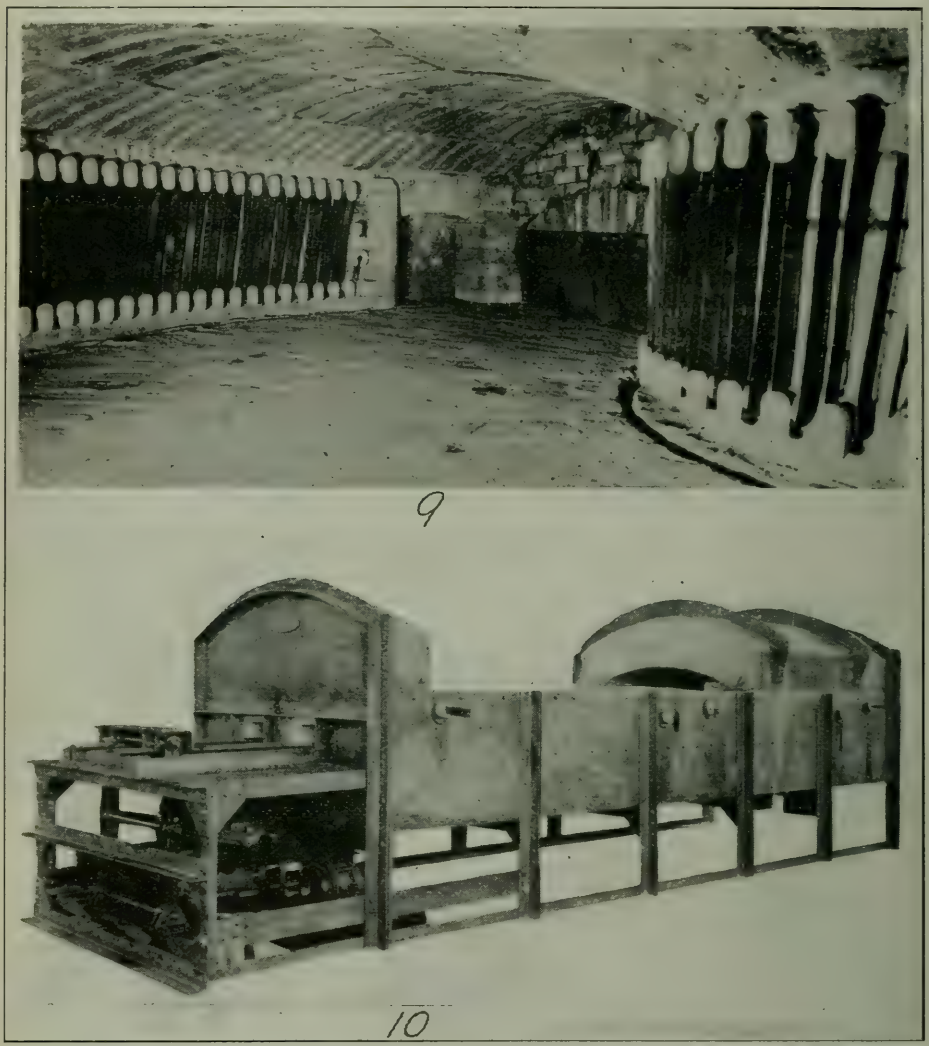


Fig. 9—Interior View looking toward the Charging Door and showing the Baffle Arch between the Charging and Discharging Doors of Electric Heat Treating Rotary Furnace equipped with Automatic Temperature Control. Operating Temperature 1550°F., 3 Phase 440 Volt, Total KW 270. Fig. 10—Pusher Type Furnace for Heat Treating Connecting Rods. Two Chambers below Heating Units. Each Chamber 16′ long, 11″ wide and 8″ high. Connected Load 87KW. Operating Temperature 1650° F.

Large Diversity of Applications of Electric Furnaces

The foregoing illustrations are sufficient to show the diversity of applications to which the electric furnace has been successfully applied. It also shows that there is no one best design that can be applied to heat treating operations in general. The goal in all heat treating operations should be to suit the furnace to the requirements of the parts being heated and the shop conditions—not as has so often been the practice in the past, to suit the parts being heated and shop conditions to the furnace.

ON THE CAUSE OF QUENCHING CRACKS

By Kotaro Honda, Tokujiro Matsushita, and Sakae Idei
(Tohoku Imperial University, Sendai, Japan).

IT IS a well-known fact that during the quenching of high carbon steels in water, cracks are often formed on their surfaces. The cause[1] is generally believed to be:

(a) The non-uniform distribution of temperature in the specimen during quenching.

(b) The difference in martensitic expansion of adjacent parts during quenching.

A closer examination of the phenomenon shows, however, that the true cause is not so evident, as the sound due to cracking is often heard some ten seconds after quenching. The thermal stress is maintained so long as the temperature is not uniform throughout the specimen. For instance, in a short cylinder, about 2 centimeters in thickness and height, the difference in temperatures between the interior and exterior parts, during the first stage of the quenching process, may amount to several hundred degrees, and consequently a great stress will result, but after about ten seconds it does not exceed 20 degrees, and hence there is only a small residual stress. Again, at the moment of transformation of austenite into martensite during cooling, considerable expansion in volume occurs. In the case of rapid cooling the transformation does not, however, take place at the same moment at every point within the specimen. Hence a great stress due to unequal martensitic expansion will result which may lead to cracking, although after several seconds, during which the A1 transformation passes over the whole mass, this stress will also vanish.

If the cracks were due to the two causes above-mentioned, why do they not take place during the first stage of quenching, when the specimen is undergoing a large amount of internal stress, and why do they take place after a lapse of time? It is, of course, conceivable that at a very high temperature the material yields to an enormous thermal stress, and therefore this stress is subsequently released, in which case a thermal stress of considerable magnitude may result at room temperature and may be the cause of the cracks occurring some ten seconds after quenching. The fact that in a high carbon steel, when quenched from a sufficiently high temperature, the cracks are produced immediately after quenching, shows, however, that a greater part of the thermal stress is not released by yielding, otherwise the immediate cracks would not take place at all.

It is a well-known fact that quenching cracks can often be observed in carbon steels or in steels with a small content of other elements, but that it is hardly possible to obtain such cracks in pure metals. These facts lead to the conclusion that the above causes of cracks are not sufficient to account for the observed facts. The present investigation was therefore undertaken to find the real cause of the phenomenon in question.

In order first to show that the cause of quenching cracks is not pure thermal stress, the following experiment was first made: Several cubes, 2

1. McCance, *Journal* of the Iron and Steel Institute, 1914, No. II pp. 235, 247.

A paper presented at the annual meeting of the Iron and Steel Institute, May 5-6, 1921.

centimeters on each side, were made of steel containing 1.26 per cent of carbon, and each cube was attached to the end of a thick iron wire, 2 millimeters thick and 30 centimeters long, by means of which it could be placed in the center of an electric furnace, and be quickly removed for quenching. The furnace was of the resistance type, 25 centimeters long, consisting of a nichrome wire; its temperature was measured by means of a platinum and platinum-rhodium couple. The cubes were quenched in water from different high temperatures, and the quenching temperature at which cracking occurred was observed. If the crack did not occur, the same cube was used twice for quenching, and then renewed; if it cracked, a new one was always substituted.

The following table contains the result of the experiments:

Table I

Heating

Quenching Temperature Degrees Centigrade					
680	700	750	770	800	830
Remarks—No Crack	No Crack	No Crack	No Crack	Crack	Crack

Cooling

Quenching Temperature Degrees Centigrade—Specimens first heated to 900 degrees Centigrade, then cooled and quenched

800	770	750	730	710	690
Remarks—Crack	Crack	Crack	Crack	Crack	No Crack

From the above table it is seen that during heating the crack does not occur unless the quenching temperature exceeds 800 degrees Cent. During cooling from 900 degrees Cent. the quenching cracks is always observed down to a temperature of 700 degrees Cent. and not observed at any lower temperature. This limiting temperature is much lower than that during heating. As is well known, the Ar1 point is always lower by about 40 to 80 degrees Cent. than the Ac1 point; hence, from the above result of quenching experiments, it may be concluded that during heating or cooling the crack occurs when, and only when, the quenching temperature exceeds the Ac1 or Ar1 point, respectively. Hence the cause of quenching cracks is not pure thermal stress caused by non-uniform distribution of temperature due to rapid cooling, because if such were the case, there would be no reason for the cracks occurring beyond the A1 point. The cracks must, therefore, have some connection with the A1 transformation.

In a soft quenching, cracks usually occurred in ten to fifteen seconds after quenching in water; they could be distinctly detected by the sounds accompanying cracking. The same fact also indicates that the thermal stress is not the direct cause of cracking because the cracking occurs after a lapse of time, where a greater part of the thermal stress due to the unequal cooling of the specimen passes off. As is well known, during cooling through the Ar1 point the specimen undergoes a considerable expansion due to the A1 transformation.[2] Since during cooling the outer portion is always at a much lower temperature than the inner portion, the former, during the said transformation, exerts a great impulsive tension on the latter, and this may cause a crack in the specimen. But the fact that cracks often occur after the impulsive stress due to the Ar1 transformation is passed over, shows that the impulsive stress is not the actual cause of quenching cracks.

It was also thought desirable to make a similar experiment with a speci-

2. K. Honda, *Science Reports*, Vol. VI (1917), p. 203.

men having no A1 transformation, which was, however, at least as brittle as quenched carbon steels. An alloy steel containing a considerable amount of chromium and cobalt possessed such a property. The experiment with the steel showed that, from 550 degrees Cent. upwards, very superficial but irregular cracks gradually appear, but vanish, however, with a light polishing. As the quenching temperature rises, the cracks become deeper and deeper,

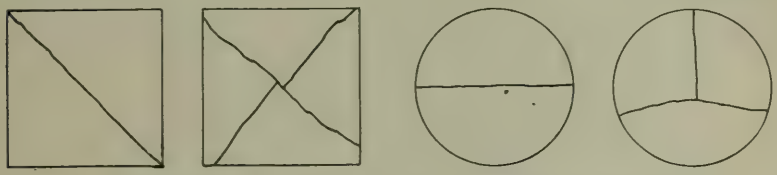


Fig. 1—Crack lines due to thermal stress in quenched carbon steels.

but remain always irregular. Quenched from 1000 degrees Cent. they are still much finer than those in carbon steels. The quenching of a cast iron from different high temperatures shows also similar cracks. Thus, crack lines due to pure thermal stress are very fine and irregular, and can easily be distinguished from very simple crack lines (Fig. 1) in quenched carbon steels, which are the object of the present investigation.

To get a general idea of the rate of cooling during quenching, a cylindrical piece having the same dimensions was made of the same material as the test specimens. It had two holes bored parallel to its axis and to its middle height, their inner diameter being each 2 millimeters; one hole was bored at its center and the other just inside the lateral surface. In one experiment a platinum and platinum-rhodium couple was well insulated and inserted into the middle hole, its junction being, however, bare and in direct contact with the specimen, while the other hole was packed with kaolin. In another experiment the couple was inserted into the side hole while the central hole was packed with kaolin. In each case the cooling was measured by a millivoltmeter with a pivoted needle inserted in the circuit of the couple, the motion of the needle being almost dead beat. Fig. 2 shows graphically the result of the observations. From curves (1) and (2) it is seen that the temperature of the specimen at its center and at its lateral surface falls initially very slowly, and then rapidly, increasing in its rate till it reaches a maximum and then gradually decreases. Curve (3) is the difference-curve between curves (1) and (2); thus the difference in temperatures between the center and the lateral surface is at first zero, but rapidly increases, reaching its maximum value at about 3.5 seconds and then decreases, till it almost vanishes at 13 seconds. The maximum difference in temperatures in the specimen amounts only to about 300 degrees Cent.

The result of quenching experiments will be next described. The investigation consisted of the measurement of hardness in quenched specimens by means of a Shore scleroscope, the distribution of internal stress being thus found. Four kinds of carbon steel containing the following constituents were chiefly investigated:

No.	Carbon Per Cent	Manganese Per Cent	Silicon Per Cent	Phosphorus Per Cent	Sulphur Per Cent
1	.28	.25	.42	.032	.070
2	.68	.51	.19	.019	.037
3	.91	.31	.11	.027	.004
4	1.47	.25	.34	.040	.004

The specimens were tested in the form of a cube, each side being 2.7 centimeters, or a short cylinder, 2.6 centimeters in diameter and in height. On a surface of the cube or the cylinder a narrow hole, about 3 millimeters deep, was bored, and a thick steel wire screwed in, as shown in Fig. 3; this wire served as a holder in the subsequent work. The specimen was placed horizontally in an electric furnace of nichrome wire, and heated to the required temperature. After maintaining the specimen at this temperature

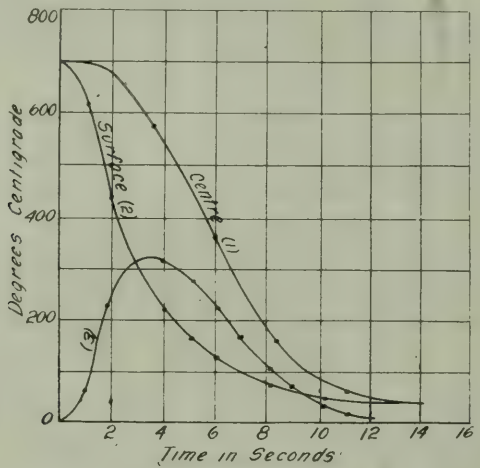


Fig. 2—Curves showing cooling of cubes

for ten minutes, it was quickly taken out of the furnace and dipped vertically into a water or oil bath, followed by a constant stirring, until the temperature of the specimen fell to that of the bath. The specimen thus quenched was polished with emery paper; sometimes it was at first ground with carborundum, care being taken, by dipping it frequently in water, not to heat the specimen too much, since heating may affect the structure and consequently its hardness. The specimen was placed on the platform of a Shore scleroscope, and the position of a point, at which the hardness was to be measured, was read on a section paper pasted on the platform. In the case of the cubes, the number of points by which the hardness was measured amounted to 36, and sometimes more, if necessary. These 36 points were divided into three groups, the outer group consisting of 20 points at the periphery, the inner group 4 points about the center, and the middle group 12 points situated between these two. In the case of cylindrical specimens, the number of points amounted to 24 in all, the outer group being 12, the middle 8, and the center 4. In cases when the general character of the distribution of hardness is to be sought, the mean value of hardness in each group was taken.

The results of experiments showed that:

(1) In a soft quenching, such as in oil from a temperature not exceeding 820 degrees Cent., the hardness of different specimens is greatest in the outer portion, and decreases from its periphery towards the center.

(2) In a medium quenching, such as that of a steel 0.9 per cent carbon at 780 degrees Cent. in water, or that of steel 1.47 per cent carbon at 900 degrees Cent. in oil, hardness is nearly constant everywhere.

(3) In a hard quenching, such as that of steel containing more than

0.68 per cent carbon from 800 degrees Cent. or a higher temperature in water, the hardness is least in the outer portion and increases rapidly toward the center.

(4) When cracking takes place, lines of cracking cut equi-hardness curves almost orthogonally. The form of equi-hardness curves is elongated in a direction normal to the line of cracking.

(5) In the cubes, the equi-hardness lines become roughly circular or elliptical at a short distance from the periphery. The same remark applies naturally to the case of cylindrical specimens.

(6) By grinding away a few millimeters from the surface layer step

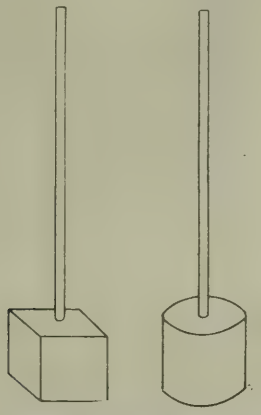


Fig. 3—Sketch showing manner in which specimens were mounted for quenching and hardness tests.

by step, the irregular deviation of equi-hardness curves from a circle or an ellipse gradually diminishes.

In the present experiment, cracking occurred in most cases, when the temperature of the specimens fell nearly to that of the bath. To show the relation between the hardness and the quenching temperature, the results of experiments are given in Figs. 4 and 5, from which the following well-known facts may be inferred:

(7) The hardness does not increase appreciably, so long as the quenching temperature is below the Ac1 point.

(8) When the quenching temperature increases beyond the beginning of the Ac1 range, the hardness rapidly increases, reaches a maximum at about 820 degrees Cent. and afterwards slightly decreases.

From the curves in Figs. 4 and 5 we also see that the hardness of the outer portion is least, that of the middle portion considerably greater, and that of the central portion greatest.

One important fact discovered by the present investigation is that in a hard quenching the outer portion is softer than the inner. This abnormal phenomenon is satisfactorily explained by the theory of quenching put forward by one of the present writers.[3]

According to that theory of quenching, the so-called A1 transformation is not a single, but a compound transformation, consisting of

Austenite to Martensite to Pearlite

Thus, during a slow or rapid cooling, austenite is at first changed into mar-

3. K. Honda, *Science Reports*, Vol. VIII (1919), p. 181.

tensite, which is then transformed into pearlite. During a very rapid cooling, such as a quenching, the change from austenite to martensite is so far retarded that when it is completed the specimen is nearly at room temperature, and therefore the next change from martensite to pearlite cannot progress, owing to the high viscosity of the material at room temperature. During a slow cooling austenite changes into martensite, and the latter, still at a very high temperature, changes immediately into pearlite. During heating, the A1 transformation consists in the reverse change, that is, from pearlite to austenite through martensite.

With regard to the volume per unit of mass, the relation is:

Austenite is less than martensite and martensite is greater than pearlite;

for martensite is known to exist in a more dilated state than pearlite, and the latter in a more dilated state than austenite, as is seen from the expansion curves[4] at high temperatures. Hence in the A1 range, during slow cool-

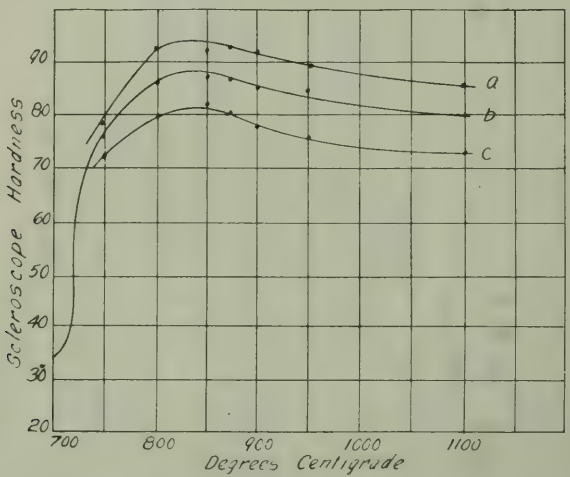


Fig. 4—Curves showing the relation between quenching temperature and hardness of a .68 per cent carbon steel. (a) inner group, (b) middle group, (c) outer group.

ing, the elongation is a differential effect of the expansion due to austenite going to martensite and of the contraction due to martensite going to pearlite; during slow heating, the contraction is a differential effect of the expansion due to pearlite going to martensite and of the contraction due to martensite going to austenite.

In quenching experiments, the rates of cooling in the outer and inner portions of the specimen differ considerably from each other. In the outer portion, where cooling is very rapid, not only the second change of the A1 transformation—martensite to pearlite—is stopped, but also its first change—austenite to martensite—is partially arrested, so that this portion contains a certain amount of austenite intermingled with martensite. In the inner portion the rate of cooling is not so rapid, and hence the austenite is mostly transformed into martensite; but its further transformation into pearlite is arrested. Since the austenitic structure is much softer than the martensite structure, it is to be expected that the outer portion, containing a greater proportion of austenite than the inner portion, will be softer than this portion.

If the above view is correct, for a soft quenching such as quenching in

4. K. Honda, *Science Reports*, Vol. VI, (1917), p. 203.

oil from a moderately high temperature, the outer portion may be just fully martensitised, while in the inner portion the transformation from martensite to pearlite is partial. In this case, the outer portion must be harder than the inner portion, as is actually brought out by experiments. In a somewhat harder quenching than in the last case, the outer and inner portions may possess nearly the same hardness. The fact that above 820 degrees Cent. the hardness gradually decreases as the quenching temperature increases, is explained by the same theory, that is, by a gradual increase of austenite arrested and mixed in martensite.

Several quenched specimens were examined microscopically, to see

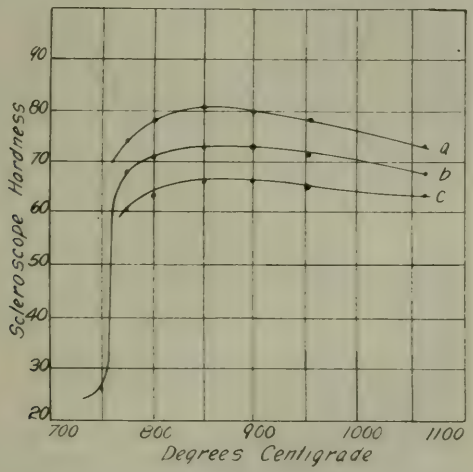


Fig. 5—Curves showing the relation between quenching temperature and hardness of a .28 per cent steel. (a) inner group, (b) middle group, (c) outer group.

whether any appreciable decarburization actually occurred; but except narrow edges, or at least in portions where hardness was measured, decarburization was negligibly small. Hence the less hardening of the outer portions cannot be explained by decarburization. It is the common experience of smiths that by quenching pieces of steel in water, the edges are much softer than other portions; this fact is usually explained as the effect of decarburization during heating. In many cases, however, it is caused by the arrested austenite during quenching.

The cause of cracking was next investigated in a series of equi-hardness curves for a number of carbon steels with varying percentages of carbon, quenched from varying temperatures. These curves accompanied the original manuscript, but as their reproduction would have been attended with certain difficulties, they have been omitted from the paper, and are filed in the Institute library, where they can be consulted by any member interested in the subject. Since the form of the equi-hardness lines was elongated in the direction perpendicular to the line of cracking, it is to be concluded that the martensite development is greatest in the elongated central portion and least in the periphery; hence the martensite expansion in the former portion is much greater than that in the latter portion. The central portion exerts, therefore, a great tension on both sides, this tension causing the cracking of the specimens. This is why lines of cracking are normal to

the elongated equi-hardness curves. Since the difference in the specific volumes for martensitic and austenitic structures increases rapidly as the temperature falls, it may be understood why cracking generally occurs when the temperature of the specimen approaches to room temperature.

Having thus far explained the distribution of hardness and crack lines, the question of how to avoid quenching cracks arises. In quenching practice it is not necessary to get very great hardness, except in the case of cutlery. It is also evident from the above investigation that to obtain a martensitic structure too rapid cooling is unnecessary. In order, therefore, that the specimen may not crack during quenching, but that its hardness be properly developed, quenching must be medium hard, such as quenching in oil from 900 degrees, in which case the hardness is nearly constant throughout the specimen; hence the stress due to the difference in the structures is small, and consequently cracking cannot occur. For a given steel, the quenching temperature of no cracking can be experimentally found in the following way: The specimen is quenched in oil from three different temperatures, 800, 900 and 1000 degrees Cent., and the hardness at the outer and central portions is measured. Two curves of hardness-quenching

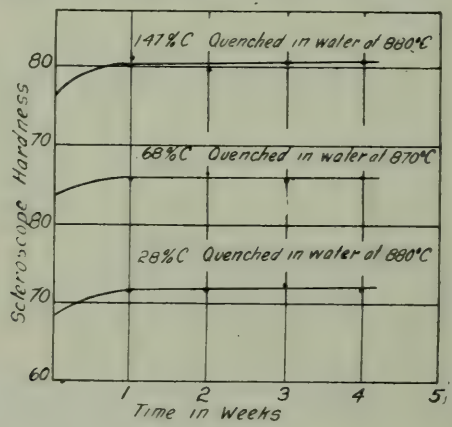


Fig. 6—Graphical representation of experiments to determine the change in hardness of a quenched steel when allowed to stand at room temperature.

temperature for these two portions are drawn. The temperature corresponding with the intersection of these curves is that required; for quenching at that temperature causes nearly equal hardness in the outside and central portions.

According to the above view, in a hard quenched steel some austenite remains untransformed at room temperature, at which this austenite will slowly transform into martensite. On the other hand, at room temperature martensite has a tendceny further to be transformed into troostite, but its velocity is much smaller than that of austenite going to martensite just referred to. The consequence is that at room temperature a hard quenched specimen will slowly increase its hardness with lapse of time. To test this inference the hardness of a quenched specimen was measured from time to time in the usual way, and its mean value plotted against the time passed after the quenching. Fig. 6 is a graphical representation of the result of the experiment, which agrees completely with expectation. The hardness

increases at first rapidly and then slowly, tending to an asymptotic value, as the time elapses.

If the quenched specimen be constantly heated at 100 degrees Cent., instead of letting it remain at room temperature, the above change from austenite to martensite will be much accelerated; at the same time the change from martensite to troostite will also be accelerated. Hence the hardness first increases, reaches a maximum, and then slowly decreases. As shown in Fig. 7, this conclusion is actually brought out by exeriments.

In quenching a large piece of steel the distribution of hardness in the outer layer is exactly the same as in the case so far discussed; but in the

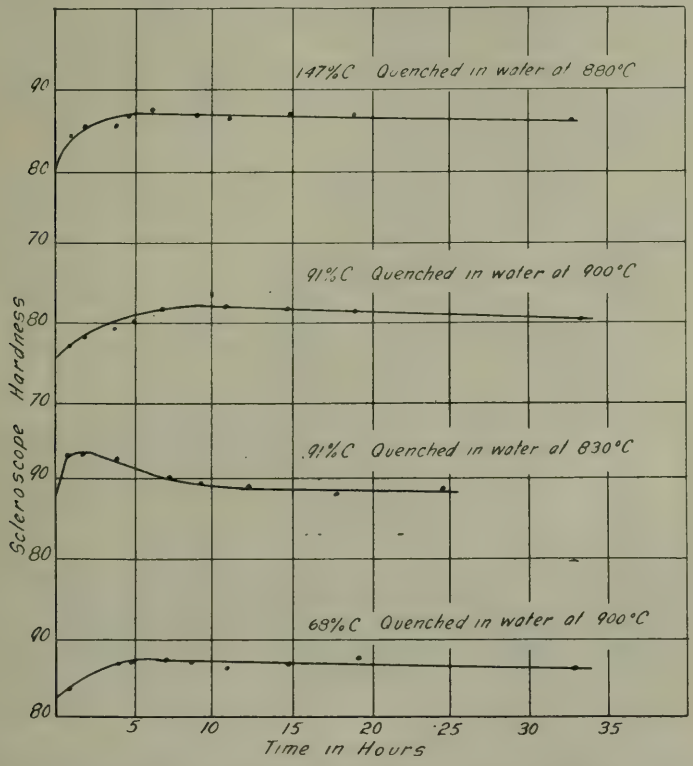


Fig. 7—Graphical representation of experiments where a quenched steel is constantly heated at 100 degrees Cent. The hardness first increases, reaches a maximum and then slowly decreases.

innermost portion, where cooling is slow, the microstructure becomes troostitic, and therefore the hardness is here considerably smaller.

Now, the contraction-temperature curve for steel rod during slow cooling[5] or quenching[6] has been already determined and found to have a form as shown by curve (*a*) or curve (*b*) in Fig. 8. The curve (*a*) is the ordinary contraction-curve for a slow cooling; the curve (*b*) for quenching begins to elongate from 200 degrees Cent. downward, and at ordinary temperature the length of the rod is much larger than that in the case of slow cooling. This elongation is the expansion, accompanying the transformation

5. K. Honda, *Science Reports*, Vol. VI, l. c.

6. Ibid., Vol. VIII (1919), p. 169. P. Chevenard, *Comptes Rendus* (1919), p. 17.

from austenite to martensite, the further transformation from martensite to pearlite being arrested. Hence, in quenching a large specimen, its outer portion contracts along a curve similar to curve (*b*), while the inner portion contracts in a manner similar to curve (*a*), and therefore during cooling through the A1 range the inner portion is in a more dilated state than in the latter portion. Hence the outer portion undergoes a large tension, and this tension superposed on the thermal stress may cause the cracks in the specimen at high temperatures. In a hard quenching, crackings are often found to take place immediately after quenching in water; this kind of crack is probably due to the stress just referred to. By a further cooling of the specimen, the tension acting on the outer portion begins to decrease at some 200 degrees Cent. becoming zero at a certain lower temperature. It then changes

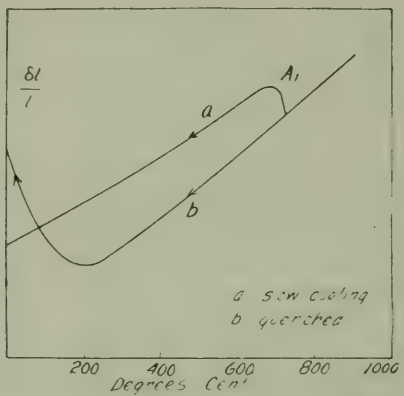


Fig. 8—Curve showing change in stress of a specimen in quenching.

into compression, its magnitude increasing rapidly as the temperature falls to room temperature. These changes of stress will easily be understood from Fig. 8. In approaching room temperature the temperature of the whole specimen becomes nearly uniform, and hence the thermal stress vanishes.

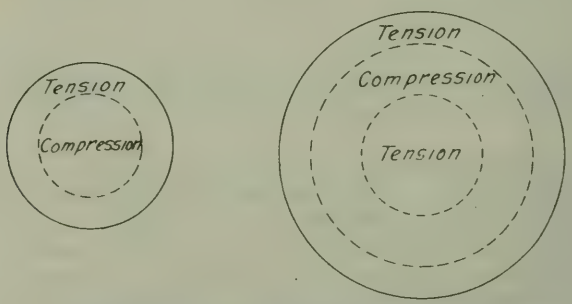


Fig. 9—Diagrammatic sketch illustrating the stresses present in a large and small cylindrical specimen quenched in water.

By virtue of the above stress the inner portion undergoes a tension from the outer portion; this outer portion also exerts a tension to the outmost portion

of the specimen by the strain exerted in the foregoing sections. The result is that the intermediate layer exerts on both sides large tension; if it be sufficiently large, cracking of the specimen may take place in the vicinity of room temperature. Thus the nature of the stress present in small and large cylindrical specimens which are quenched in water may conveniently be illustrated in Fig. 9.

Summary

The result of the present investigation may be summarized as follows:

1. In a quenched steel a certain amount of austenite is generally present intermingled in martensite. The amount of this austenite increases as the quenching temperature increases.

2. In small pieces of steel the periphery is harder than the central portion only when the quenching is very soft. In a moderate quenching the hardness is everywhere nearly equal, but in a hard quenching the periphery is always softer than the interior. This anomalous phenomenon is explained by the presence of the arrested austenite in martensite.

3. The quenching cracks in small pieces of steel occur when the hardness in the central portion is much greater than in the periphery. The cause of the cracking is attributed to the stress caused by the difference in the specific volumes of austenite and martensite; the specific volume of the former structure being much smaller than that of the latter the central portion exerts a large tangential tension on the periphery, causing thereby the cracking of the specimen.

4. Since the difference in the specific volumes increases as the temperature falls, the cracking usually takes place when the temperature of the quenched specimen approaches room temperature.

5. In a hard quenching, the hardness generally increases with the lapse of time, owing to a gradual transformation of the arrested austenite into martensite.

6. In the case of a large specimen, cracking may take place in the A1 range, and also in the vicinity of room temperature. The cracking at the high temperature is chiefly caused by the stress due to the structural difference between the inner and outer portions—pearlite and austenite—just below the A1 point; that at room temperature is due to a similar stress as in the small specimens.

ELECTRIC FURNACE MELTING PRACTICE

By E. G. Stedman

Abstract

Electric furnace production of steel has become a very important factor in the manufacture of high grade steels and the author of this paper has reviewed in a practical way the factors entering into this problem. He discusses the type of equipment he is using, the methods of procedure, including laboratory tests and forge and chill tests used in controlling the melting practice.

The author outlines the casting practice, the ingot forging practice, the rolling practice and the billet piercing practice as carried out at his plant. In conclusion he summarizes the points wherein he believes that electric furnace melting practice surpasses that of the open-hearth practice.

FOR those who are unacquainted with the general layout of an electric furnace steel plant, adapted to the production of finished seamless tubes from the raw material, the writer has endeavored to outline briefly the equipment and the procedure necessary for their production.

The steel producing department of the company with which the writer is connected was installed primarily for the production of steel to be used in the manufacture of their own product, namely, roller bearings—the steel required for their manufacture being what is known as carburizing steels, consisting of two grades (both low carbon), one grade containing one per cent chrome; the other .50 per cent chrome. By producing our own steel, a very close watch can be kept on it from the raw to the finished material.

Equipment Used

The electric furnace melting department consists of the following: four 6-ton basic Heroult electric furnaces, using 22,000 volts, three-phase primary, transformed at the furnaces to 110 volts, operating on 17-inch diameter carbon electrodes; two 20-ton cranes; an hydraulic stripper, etc.

The press department consists of one 625-ton hydraulic press; one 3000-pound manipulator, in addition to two 2-hole combination oil or natural gas fired soaking pits. Also, a bar mill consisting of one 22-inch Standard Engineering four stand, three high mill; tilting tables; continuous furnace, hot bed, hot saw, etc.

Procedure of Manufacture

The steel produced by this equipment is made from scrap especially selected as to its physical character and chemical analysis. After having been rigidly inspected and passed upon, it is unloaded by magnet in the electric furnace building, and is brought up to furnaces as required after being reloaded in scrap skips,—the contents of two of these skips being sufficient for one entire heat. These skips are first weighed and placed opposite charging doors of furnaces before the previous heat is tapped—this to facilitate the charging operation which begins immediately after the heat has been tapped and bottom made up.

A paper presented before the Detroit Chapter. The author, F. G. Stedman, is connected with the Timken Roller Bearing Co., Canton, O.

All charging is done by hand and it requires approximately thirty minutes to put in the entire charge. It might be added that this scrap is used in proportions of 50 per cent of what is known as heavy scrap and 50 per cent turnings. The power is then applied at the rate of 500 to 600 kilowatts per phase for approximately 2½ hours, after which time the bath is completely melted down. At intervals, however, during this melting-down period, the scrap must be broken loose and pushed away from the banks toward the center of the furnace—this to facilitate the time of melting-down period—as the greatest heat is obtained in the immediate vicinity of the electrodes which are in the center of the furnace. After the scrap is all melted down, the power is reduced to approximately 200 kilowatts per phase until such time as the first or dephosphorizing slag is rabbled off.

Laboratory Tests to Determine Composition

Before this slag is removed, a test is taken and forwarded to the chemical laboratory for the determination of carbon and manganese. However, before this test is sent to the laboratory, it is fractured and the carbon read by the furnace operator. If, in his estimation, the carbon is too high, the bath is *scaled* down to the required carbon content. In the meantime, a check on the fractures, as read by the melter, is obtained from the laboratory and the heat is now ready for the removal of the dephosphorizing slag which is done by the use of wooden rabbles, requiring for this operation approximately ten minutes.

In the event of the carbon being too low at this stage of the heat, a recarburizer in the form of coal or coke is added immediately after this slag is rabbled off. The final or finishing slag is then applied to the bath in the following proportions: 400 pounds of lime, 30 pounds of silica sand and 20 pounds of fluor spar. Power is again applied at a reduced rate, melting this slag in approximately ten minutes, after which time coke dust and fluor spar are added and the heat worked until such time as a calcium or carbide slag is obtained.

Another test known as the preliminary is then taken from the bath and forwarded to the laboratory, determining from this test the carbon and manganese content. Up to this time, in the making of ordinary steel, carbon and manganese are held at a point slightly below that required by the specification, after receiving determinations on these two elements, the final addition of pig iron is then made to bring the carbon content to the low side of the specification. These latter additions are then allowed sufficient time for melting and becoming thoroughly permeated through the bath.

Forge and Chill Tests Important

A forge test is then taken from the bath to determine the condition of steel before the addition of silicon is made. If, in the estimation of the melter, the steel is in a thoroughly deoxidized condition, the silicon is then added, allowing approximately twenty minutes for this to become absorbed, during which time the heat is poled, making absolutely sure that the silicon is evenly distributed throughout the bath. Another forge test is then taken. If this latter test forges perfectly, the heat is then ready to tap, providing the temperature is correct,—this being

determined by what is known as a chill test. This test is made by the removal of a certain quantity of metal from the bath, noting the amount of time in seconds consumed in chilling.

Situated immediately across from the electric furnaces is the pouring platform, in front of which the molds are placed. A depressed brick and concrete base runs parallel to the entire length of the platform. On this base are set the stools,—the latter being of cast iron with a 13-inch offset to accommodate what is known as a stool tile. The tiles used are first washed with a solution of molasses and graphite; they are then placed in a heating oven, the temperature of which is sufficiently high to remove any moisture that they might contain. The molds are then set up, having a quarter inch clearance all around at the base, this being bound by a thin layer of silica sand. The molds used are of the inverted type, the top dimensions being 16¾ x 16¾ inches and the bottom dimensions 13¼ x 13¼ inches giving a taper of 3½ inches in 5 feet. On all molds there is used a hot top, this top extending down into the mold 5 inches and protruding above 7 inches. All ingots are poured to within 1 inch of the top and a thin layer of refractory material is placed on the ingot immediately after it is poured. The ingots are then allowed to stand in the molds at the pouring platform for not less than one hour, which allows sufficient time for solidification. They are then placed adjacent to the soaking pits, being allowed to remain in the molds until such time as they are charged and at no time are they turned upside down or allowed to lie on their sides. There are two sets of molds which are used alternately to insure proper temperature, and they are thoroughly washed on the inside with a solution of molasses and aluminum before being set up. This wash, after drying, prevents the steel from sticking to the mold walls during the pouring operation. By allowing the ingots to remain in the molds until such time as they are charged much heat is retained which would be lost by stripping or shaking out and allowing them to become chilled.

The ingots are removed by the stripping crane, being pulled directly out of the molds and placed in the soaking pits—eight in a pit, four parallel to each wall. After charging a pit, the temperature of the pit and charge is allowed to equalize, that is the temperature of the ingot and the pit is brought approximately to equilibrium before the gas or oil is applied. The first stage of the heating operation consists of applying the gas and air in proportions to form a heavy scale, after which time the heating operation can be continued at a more rapid rate. The entire heating operation of one individual pit will require approximately 3½ hours where hot ingots are charged.

Forging and Rolling

The ingots, after heating, are removed to a position immediately in front of the press, being held by the manipulator on the small end, the top portion being drawn out first to the required size, which is 8 x 9 inches and the discard cut. The ingot is then turned by the manipulator, and the bottom portion is forged down. From the ingot, which weighs approximately 3500 pounds there are cut two blooms of the above mentioned size, weighing 1485 pounds each. It might be added that this press is run to a capacity of approximately 175 tons of ingots for each twenty-four hours.

The blooms, after being sheared at the press, are then stacked in the mill and allowed to cool, after which they are removed to the chipping yard. By the use of a monorail crane, they are taken from the mill, weighed and piled. They are then pickled as required, chipped and inspected. After chipping and inspecting, the different compositions of steel are piled separately, awaiting removal to the mill for rolling into the following range of sizes: 1¾ to 7 inch squares and 2 to 6½ inch rounds.

These blooms when brought into the mill are again weighed and placed on a platform at the rear end of the continuous furnace. They are then pushed through the furnace by the use of a worm driven pusher, the heating operation requiring approximately two hours. They are then removed from the discharge end of the furnace by means of a cable driven pushout machine onto a table known as the transfer. From this transfer table, they are carried to the first tilting table being fed from this into the first set of roughing rolls.

Piercing

After leaving the mill from the finishing pass onto the runout table they are stamped with the heat and bar number,—this is put in various places to insure no loss of identity, as the bars are cut into multiple lengths at the hot saw which is situated at the end of the run-out table. After being sawed to lengths, the bars are allowed to cool; they are then pickled and chipped and forwarded to the tube mill for the piercing operation, which consists of heating, piercing, rolling on reducing mill, annealing, cold drawing, and cutting into finished lengths for the automatic machines.

Advantages in the Use of Electric Steel

Having outlined previously in a general description a plant and equipment for the manufacturing of automotive steels we will now deal in a limited way, as to reason we use electric steel exclusively. In the manufacture of our product, quality is the first consideration in all operations, therefore, for a concern whose chief aim is quality, to be able to follow its product through all the various fabrications, it is a valuable asset to be able to manufacture our own steel from the raw to the finished product.

You may now ask why we adopted electric furnaces in view of the fact that it costs so much more to produce electric steel than it does open-hearth steel. These queries may well be answered by showing the advantages of electric furnace steel over open-hearth steel.

1 It makes heat available very quickly and at will, owing to regulation of power input.
2 Unusually high temperatures may be obtained due to the extremely high temperatures obtainable with the electric arc.
3 More even regulation of heat, due to the automatic regulators.
4 Desired temperatures may easily be obtained and held, due as previously stated to automatic regulation.
5 Cleanest of heating agents, as no sulphur or other undesirable elements are introduced into the furnace through the heating medium.

6 Oxidizing, reducing or neutral operations may be obtained at will.
7 The electric process is the only one in which impurities are not added to the steel by the operation, such as oxygen in the gas in open-hearth practice, impure iron in the crucible, etc.
8 The only positive means of removing the undesirable element sulphur and deoxidizing at the same time.
9 The addition of alloys in the furnace instead of in the ladle as in open-hearth practice.
10 Melting of alloy steel scrap and producing a product of high quality without loss.
11 A steel with unusual wearing qualities from a standpoint of abrasion.
12 Smaller heats may be made than in the open-hearth, thereby better mixing and control.
13 Steels more free from slag inclusions, segregations, etc., due to more thorough deoxidization.
14 A more ductile steel at low temperatures, as arrived at several years ago, under an extensive test conducted by one of the steel corporation plants.
15 A much more uniform steel from a carburizing standpoint.

From a metallurgical standpoint we might now discuss the procedure of making a low carbon chrome heat, carrying .50 per cent chrome. Let us assume that the charge is all in the furnace and melted down, the next step being the removal of the dephosphorizing slag, leaving the bath after removal of the slag with a phosphorus content of .02 which as a general rule is sufficiently low for most specifications. During the first or melting-down period you naturally have a low temperature in the furnace which is beneficial because phosphorus is not readily oxidized at high temperatures in the presence of carbon. We now have a bath of steel analyzing approximately as follows: carbon .06, manganese .15 phosphorus .02, sulphur .05, adding at this time about .35 manganese, and .50 chrome. Slag is then put on in the following proportions: 400 pounds lime, 30 pounds spar, 20 pounds of coke dust. The power is raised at this time to approximately 300 K. W. per phase. About 15 minutes is allowed to elapse at which time the finishing or desulphurizing slag is thoroughly melted, the power may then be reduced, also during this period the bath is completely deoxidized by the frequent additions of carbon, the sulphur content is also reduced at this time as calcium sulphide from the lime and carbon, and manganese sulphide from the manganese. At this time a test is taken for the determination of manganese, and a furnace operator reads the carbon content from the fracture while the slag is held in the proper shape. At this time a sample of slag is taken which upon cooling shows a decided brown cast which indicates that the steel is well deoxidized, however, not completely so, therefore, small proportions of slag consisting of slack lime, fluor spar and coke are added until such time as a slag known as calcium, which is pure white and powders when exposed to the air, or a slightly grayish slag which when added to water generates a carbide odor, is obtained as either of the above is an indication that the bath is thoroughly deoxidized.

The manganese determination has by this time been received from the laboratory and perhaps shows a content of .40 while we were aiming at .55. The other 15 points are now added and well poled into the bath, however, extreme care must be taken when poling especially if the carbon is on high side of specification at this time as a mixing of slag which is highly carbonaceous will have a tendency to raise the carbon in the bath. Silicon can now be added allowing approximately 10 minutes for this element to become thoroughly permeated throughout the bath.

The heat is now ready to tap providing the temperature is as desired and is determined differentially by furnace operators. Let us assume that we are tapping on the cold side, for this test a spoon is well coated with slag, and while extremely hot, a spoonful of metal is removed from the furnace, placing the spoon on the floor and after removing the slag on top of metal, the bare metal will show a boiling or revolving motion for say 15 seconds at which time it will skull over. This is known as a chill test and is as accurate a test as any, to my knowledge. However, account must be taken that all conditions are uniform, such as temperature of the spoon, location in furnace from which metal is taken, whether on banks or from under electrodes, etc. One more spoon test must be taken and poured into the regular test mold and if the metal lays quietly, the heat is in good condition, and thoroughly deoxidized, and if good care is taken in the pouring and teeming, a good product should be the result.

It might be added that where an organization who has been trained in the making of the same composition steel day in and day out, that they naturally become more efficient in the making of high quality steel than an organization who is making a different composition steel on every heat.

Discussion Following Mr. Stedman's Paper

Mr. McCloud: I think it a great advantage to be able to hear a practical man talk on a subject like this. I am aware that the first time one gets into trouble they are apt to blame some operation of which they know nothing for their trouble, and I think it is always an advantage to be able to hear someone talk on the practical phase of an operation with which we are not directly connected, and I am sure we want to thank Mr. Stedman for his talk.

Are there any questions in connection with this paper?

Mr. Stedman: Being somewhat in the dark as to the method of procedure at your meetings, but having been advised that there are a great number of practical men present, I have therefore endeavored to prepare this paper in a practical way. The methods outlined are regular methods of practice and naturally one who is working along the same lines day in and day out does not deal with the details in a discussion of this kind to the extent that perhaps he should in talking to a group of men who are unacquainted with all of these processes.

Question: Why do you use oxides?

Mr. Stedman: Oxides are always included in the scrap charge in the form of scale. Where a carbon reduction is necessary after the melting down period, it is then added in the form of scale or ore.

Question: Then you have to take the oxides out again?

Mr. Stedman: They are automatically removed during the final period.

Question: Are a part of the oxides which are added reduced into metal?

Mr. Stedman: Yes, there is a metallic content to both ore and scale. Of course, this reduction back to the metallic state depends upon the manner in which the oxide is added and when it is added.

Question: Which form of oxide do you prefer to use?

Mr. Stedman: Scale in the electric furnace and ore in the open-hearth.

Question: Do you remove all of the scale?

Mr. Stedman: We have just discussed that in respect to the melting down operation, however, the pressing or rolling-in of scale whereby pickling will not remove it can be almost wholly eliminated in the case of the pressing operation by the use of an air blast on the press die. This operation would not be practical in the rolling operation, especially on blooms, billets, bars, etc. However, I might add that salt lightly spread on the surface of plate steel just before the finishing pass is very beneficial, and I have also seen burlap sacks used where an extremely smooth surface is desired.

Question: You stated that you prefer to tap heats on the cold side. Just why do you prefer this?

Mr. Stedman: Personally, I prefer to tap heats on the cold side, as I have experimented extensively as to tapping temperatures. I can give no concrete explanation of this, except that we get a product more free from small seams. Another benefit that may be derived from tapping on the cold side is the longer life of ladle linings. I will admit, however, that a number of steel makers insist upon tapping on the hot side, holding the heat in the ladle to allow the elimination of gases. This would indicate, to my way of thinking, that the heat coming out of the furnace was not thoroughly deoxidized. It is true, however, that a certain amount of oxygen is carried into the molds in the pouring operation by the stream, therefore, I think it very beneficial to use the smallest nozzle possible. The item of tapping temperature has been discussed a number of times and no doubt we will always disagree, as we have in the past as to temperature.

Question: What temperature would your pyrometer show in pouring low carbon steel heats such as you make?

Mr. Stedman: It would show approximately 2700 degrees Fahr. on low carbon steel.

Question: Is it imperative to coat your molds with some type of wash?

Mr. Stedman: Yes, to my mind this is very important. I have experimented with a number of different mold washes in the past, and have obtained the best results with a solution of molasses, aluminum and water. However, the good results obtained are not entirely due to this wash, but to the temperature of the mold when washed, which is very important, as the mold temperature has a tendency to burn out one ingredient, leaving the other. The use of different coatings, I think, is best determined by the kind of steel you are making, facilities for applying same, etc.

Another thing to be taken into consideration in a mold wash is

a grade of material that will resist the splashing which naturally occurs in the pouring operation from sticking to the mold wall.

Question: I would like to ask where you get the steel for the Timken plant?

Mr. Stedman: At one time we had sufficient ingot capacity in our own plant to supply all our material needs, but at the present time it is necessary to resort to outside sources.

Question: Do you use the direct forge method?

Mr. Stedman: Yes.

Question: What if the forge bar breaks?

Mr. Stedman: That would indicate that the steel was short, the manganese being too low.

Question: Do you read carbon on the forge test?

Mr. Stedman: No, a separate test is taken for this purpose. The forge test is poured in a round mold to facilitate handling.

Mr. McCloud: Evidently it is quite surprising for anyone the first time they watch the operation around a steel furnace to see how closely the operator can read the fractures and determine the carbon of the heat. Few men that have never been around a furnace can realize how accurately this can be done.

Question: Where was the first successful electric furnace operated?

Mr. Stedman: I think Halcomb claim that. Is that true Mr. Atkinson?

Mr. Atkinson: I think this is an established fact that Halcomb was first on tool steel, Lebanon on steel castings and South Chicago on large ingots.

Question: May I ask why you cast such large ingots?

Mr. Stedman: To get more reduction and obtain two blooms of the size that we require for our mill.

Question: Is it true that your molds are tapered?

Mr. Stedman: Yes, they are tapered from top to bottom, this taper being on the inside. The wall thickness at the bottom being 5¾ inches and at the top 3 inches.

Question: During the war there was considerable discussion as to flaky structure. Are you troubled with this condition?

Mr. Stedman: No, I think that was entirely confined to the plants making gun steel, and we made no gun products whatever.

Question: How does the cost of producing steel with the electric furnace process compare with that of the open hearth?

Mr. Stedman: It is cheaper to produce than open-hearth, naturally.

Question: I mean actual cost of production?

Mr. Stedman: For the sake of argument, I will say that comparing two efficiently operated plants there would be a variation of approximately $5.00 per ton, but when you take into consideration the uniformity and superior quality of electric steel, I think it can be said without a question that an electric steel can be made as cheaply as open-hearth steel.

Question: In regard to scrap free from oxide and scrap covered with oxide, which do you consider most beneficial?

Mr. Stedman: Scrap heavily covered with oxide is beneficial in making low carbon steels, as the oxide which would have to be added

in the making of high carbon steel is more evenly distributed throughout the scrap.

Mr. McCloud: You mean so far as your operations are concerned, in making a heat of low carbon steel it would be somewhat of an advantage to have rusty scrap?

Mr. Stedman: One drawback, however, in using very rusty scrap is the fact that you buy oxide, paying a steel scrap price for something that can be bought for about 60 per cent less.

Unannounced Speaker: We had a talk last winter by a man who claimed to be an authority on that subject, who made a statement that all the trouble in the manufacture of steel was caused by rusty scrap.

Mr. Stedman: I do not agree with the gentleman, whoever he might be, as I have experimented extensively with different grades of scrap and find that a full charge of scrap heavily covered by oxide, properly worked in the furnace, you can produce steel as good as a full charge of perfectly clean scrap.

Question: Are electric furnaces always basic, or sometimes acid?

Mr. Stedman: To my knowledge no furnaces on the production of ingots are acid, this being due to the character of the scrap, which is used. In making castings most furnaces are acid lined.

Question: Is there any advantage in using an acid lined furnace?

Mr. Stedman: If you are not held to a low sulphur and phosphorous content, I would say yes, due to a slightly higher production, as there is no question but what acid steel can be made with greater speed and also the fact that you do not add ferrosilicon, which is an expensive addition.

Question: How closely do you control your carbon content?

Mr. Stedman: Our specifications call for between 15 and 20 points.

Question: What is the carbon content of the case in a finished bearing?

Mr. Stedman: I would say that it is approximately 1.00 per cent, of course, as you understand, the core remains as originally, stated 0.15 to 0.20 per cent.

Question: In the washing of molds just how is this wash applied?

Mr. Stedman: We use a brush.

Question: Would it not be better to spray this on?

Mr. Stedman: We tried out the spray, but found there was a considerable loss, as spraying was much too fast.

Question: Do you use standard aluminum?

Mr. Stedman: No, we use what is known as "varnish aluminum," which when rubbed between the fingers has the appearance of paint.

Mr. McCloud: Is it the same aluminum that is used on radiators, etc.?

Mr. Stedman: Yes.

Mr. McCloud: How does the length of life of an electric furnace compare with the open hearth?

Mr. Stedman: An electric furnace has to be relined more often.

Mr. McCloud: The question being brought up, I wonder if anyone here knows anything about a controversy in difference of opinions as to acid and basic lined furnaces. I believe that a certain amount of reason for the difference in practice depends upon local supplies. For

instance, I believe the general American practice in production of open-hearth steel is in the basic furnaces, but understand that European practice is the reverse, the same being true with the bessemer practice. I was of the opinion that the larger portion of bessemer steel in this country was made in an acid converter, whereas, on the other side it is made in basic converter.

Unannounced Speaker: The answer to the converter problem is very simple. There were practically no iron works running basic converters in this country a few years back, as the slags were used for phosphorous fertilizer. I know of one company in this country, who have for a considerable time ran two furnaces on acid and one on basic, their reason being that they could balance up their products, which were castings, as to specifications. As a rule acid open-hearth practice is more simple than the basic, but the basic enables one to reduce elements which you could not reduce in the acid furnace. In other words, basic opens to you an old line of refining.

If you attempted to refine in the acid furnace as you do in the basic it would naturally chew the lining out. It is largely a question of the product you have to produce.

Mr. Atkinson: Has anyone here made any considerable number of tests on steel made in both basic and acid open-hearth furnaces, also is there any difference in the steel?

Unannounced Speaker: I do know that during the war both the French and British governments allowed 0.05 per cent lower carbon for acid than for basic steel.

Question: For shell steel?

Mr. Stedman: Yes.

Mr. McCloud: For the same carbon content, would it be possible to obtain higher physical properties from acid steel than basic steel?

Mr. Stedman: Yes, the physical properties would run slightly higher.

TOP DISCARD IN ITS RELATION TO QUALITY

By A. E. White

Abstract

The author of this paper makes an appeal to the steel mills to increase their tonnage output by adopting methods and devices for reducing the amount of piping and segregation, thereby increasing their total yield per ton of metal cast into the ingot molds.

During the World war the government required that a 25 per cent top discard be taken from each ingot rolled into shell stock. In numerous cases it was shown that a lesser amount of discard resulted frequently in defective finished billets.

It has been shown that the mills can work to rigid specifications without experiencing any undue hardship after they adjust their conditions to meet the demands of the specification, with the result that they reduce their spoilage and increase their quality.

Introduction

WE ALL object to the use of alibis by others. Yet who is there who has not used them to a greater or a lesser degree in the days gone by? Many believe that within reason their use may be warranted. We have in our midst those who would not use an alibi to conceal fault or sin, yet would use one if by doing so they believed they would prevent pain or grief.

What is true of individuals is true, within certain limits and at certain times of business. Fundamentally, business, be it large or small, is honest. There are times, however, when alibis have been employed both consciously and unconsciously.

In the steel industry we have accepted for so long a time the various alibis explaining the reasons for imperfections, that we have come to believe them more or less as truths. We have really come to believe that it is necessary for us to take a certain amount of the bad with the good when purchasing steel. We have come to believe that every failure to receive good steel has had a satisfactory explanation.

In the days preceding the World war, we accepted as truth that it was impractical to put into effect certain items of control which would result in the procurement by the consumer of nearly perfect stock. The difficulties surrounding satisfactory inspection were so forcefully presented that we believed it would be impossible to get a better grade of stock—commercially speaking—than we were then receiving. Our friends, from across the water in the procurement of their munition steel, showed us the alibi and proved that adequate inspection at steel mills could be conducted without a fundamental reduction in output.

Immediately after the war, in the period of frenzied business, the alibi for lack of quality was laid at the door of the large number and size of the orders on the books of the steel mills. In 1921, at a time when the normal person would have assumed that it would have been possible to surround the production of steel with every safeguard, we found certain of the mill interests

A paper presented before the Pittsburgh chapter of the society. The author, Col. A. E. White, is director of the department of engineering research of the University of Michigan, Ann Arbor, Mich.

presenting a further alibi, namely, they claimed that because of the reduced business, because of discontinuity of operation and troubles resulting from a somewhat disorganized personnel, they were not able to make as high a grade of steel as they would make when conditions were more favorable for the smooth and frictionless running of their plant.

To those philosophically inclined, what will be the alibi presented when the steel industry has again returned to normal and when it is neither beset by the hectic days of yesterday nor the somewhat uncertain state of today?

Do not misunderstand the nature of these remarks. They are not made as charges against our steel mills. There is no more honorable business in the world and the general policies, principles and procedures are sound and straightforward. The alibis presented are, in the main, accepted as truthful explanations of the failure to meet a hundred per cent perfect output. Is it not possible, however, that both the steel producer and the steel consumer is deceived by the apparent truth of the alibis? It has been pounded into our very being for so many years that we cannot expect to get absolutely homogeneous steel, that we have come to believe that that condition actually exists. Accepting it as a truth, the consumer places before the steel mills his bill of materials and oftentimes places his contract with the firm that has made the lowest bid. This may or may not be good business. It is my personal belief, however, that to place a contract merely on the basis of cost and delivery and even general integrity of a firm without stating anything relative to freedom from piping, segregation, surface defects, etc., is trusting altogether too much to blind instinct.

Suitable Specifications Necessary

There are uses for steel which require most critical inspection. Adequate specifications for the purchase of this stock should be used. There are places where steel with inherent piping and even segregation can be used without fear of failure. Specifications should be used in this case. For the former it is assumed that a higher price would have to be charged than for the latter, for it cannot be expected that a steel mill can operate without profit and the greater care required and the greater losses involved in the production of good steel must necessarily be paid for by the consumer. The consumer should in the end profit by such increased expenditure because he should run into less operating difficulties in the various component parts in which he uses the steel and encounter, therefore, less delays and less losses as a result. For, after all is said and done, the major losses involved by the use of an imperfect steel are borne by the consumer, usually five or ten times over, even though the steel mill does willingly replace the defective product.

Inherent to a greater degree than any of us appreciate, are the troubles due to insufficient discard. For instance, during the World war one of our plants manufacturing rifle barrels was encountering much difficulty in their steel because of excessive dirtiness. On examination we found that the steel used for this purpose was undergoing a top discard of only 15 per cent, whereas steel differing but slightly in composition and costing one-fourth less was undergoing a minimum top discard of 25 per cent. When this situation was brought to the attention of the steel mill they very graciously increased their minimum top discard on the rifle barrel steel to 25 per cent with the result that the delays and losses experienced at the plant almost immediately dropped to zero.

Government Specifications

On shell steel the steel manufacturers were allowed considerable latitude with regard to composition. They were given 20 points variation leeway in carbon and equally wide latitude in manganese. They claimed that such latitude was necessary if they were to furnish the requisite quantity of steel required. This statement may be true, though if I remember correctly there was one mill located not far from Pittsburgh which kept practically every heat it made within five points in carbon and in manganese contents.

The specifications required a minimum top discard of 25 per cent and it was standard mill practice in addition to take a bottom discard of five per cent. The mills were permitted a lower minimum top discard on the submission of evidence that such a step would be justified. As a matter of passing

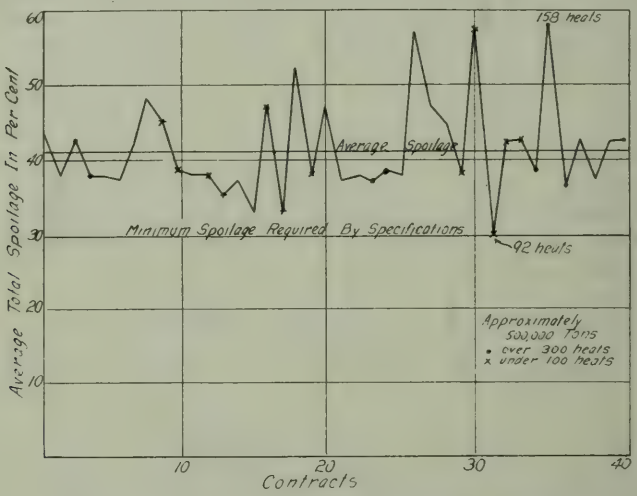


Fig. 1—Average Spoilage On Forty Contracts For Shell Steels

interest, only two mills asked for a lower minimum top discard. One of these requests was granted for about three months but was removed at the end of that time because the average mill practice did not warrant a minimum top discard below 25 per cent. The other mill was advised that on the submission of proper evidence their request would be considered. After six months had elapsed I asked the company's representative why we had not heard further from them with regard to their request for a reduction in top discard and I was informed that on looking into the matter more carefully they found that they would not be justified in presenting their request for reduction.

Spoilage on Shell Steel

I have plotted for our consideration the spoilage from 40 contracts of shell steels representing approximately 500,000 tons—see Fig. 1. The average spoilage for all of these contracts was 41.33 per cent. This is 11.33 per cent above the minimum spoilage required by the specifications. Those firms making over 300 heats have been represented by a solid black circle and those firms making under 100 heats have been represented by crosses. This designation was employed in order to ascertain whether or not the firms making

the larger number of heats had a lower spoilage than the firms making a smaller number of heats. There seems to be no striking evidence in this connection one way or the other. Apparently, therefore, the matter of spoilage is not a question of the number of heats. As a matter of interest that firm producing its quota of steel with the minimum total spoilage—namely 30 per cent—made but 92 heats, whereas a firm producing 158 heats of steel had a total spoilage of 58.7 per cent.

Shell steel was inspected more rigidly than is the case with most commercial steel, though not more so than to insure freedom from piping and undue segregation. Yet one cannot look at the curves found in Fig. 1 and

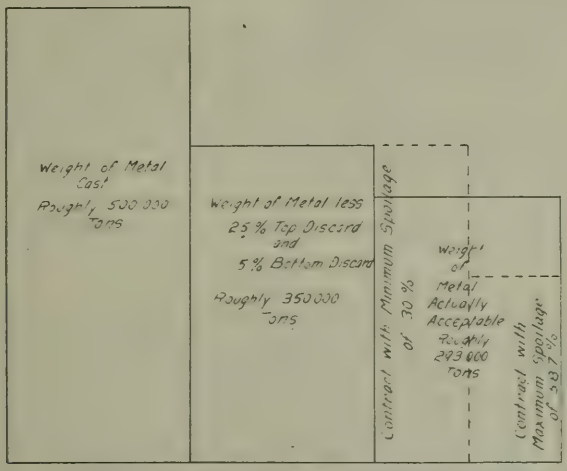

Weight of Metal Cast
Roughly 500 000 Tons
Weight of Metal less 25% Top Discard and 5% Bottom Discard
Roughly 350000 Tons
Contract with Minimum Spoilage of 30 %
Weight of Metal Actually Acceptable Roughly 293 000 Tons
Contract with Maximum Spoilage of 58.7 %

Fig. 2—Relation of Weight of Metal Acceptable to Weight of Metal Cast

on the curves found in Fig. 2—which presents a generalization of this matter, without wondering about the wisdom of making no more insistent attempts to produce steel free from piping and undue segregation.

When we realize that of these 500,000 tons of steel but approximately 293,000 tons were acceptable, and when we appreciate that of this 500,000 tons of steel nearly half or namely 207,000 tons was unusable as a first-class product and that most of it was used as remelting stock, and when we multiply these figures by six, seven or eight in order to convert them into our thirty and forty million tons, we cannot help but realize that one of the outstanding problems in the metallurgical field today of interest both to consumer and producer is the production of stock free from, or comparatively free from piping and undue segregation, without the exceedingly heavy losses set forth in these curves.

If one firm can make steel of such high quality as to require but 30 per cent total discard, if two others can approximate this record with a total spoilage of but 32 per cent, if a total of 22 firms out of 40 can make steel with a spoilage of less than 39 per cent, what is the trouble with the practice of the other 18 firms that they cannot make steel free from piping and undue segregation without a spoilage between 42 and 58.7 per cent? This question is not asked as a consumer. It is asked as one who believes that in the long run that firm or corporation which cuts its wastage to a minimum

is in a more advantageous position than that firm which tolerates sloppy practice.

It is furthermore appreciated that these spoilages are not the ones used in commercial practice. The average spoilages in the Pittsburgh district between the years 1902-1906 are given as 15.15 per cent. It is assumed that this is the average spoilage figure for today. It is my contention, however, that that firm which showed an average spoilage of 30 per cent is making a consistently better product—though today's spoilage may be but 15.15 per cent—than that firm which required a spoilage of 58.7 per cent in order to free its metal from piping, undue segregation and surface defects. It is also my feeling that that firm which showed the lowest discard with equal costs as to raw materials and freight, is making its product at a lower cost than any of the other plants, especially those that required a spoilage of over 42 per cent. This statement is made on the basis of the general observation that those plants with the best technical control, when the same is not carried to an extreme—and in none of the 40 plants listed is such the case—those with the lowest operating costs—conditions as to cost of raw materials and freight being the same—are those with the most carefully controlled practice

Mills Have Not Readily Adopted New Methods For Reducing Piping and Segregation

For some time I have wondered why our large mills did not receive more enthusiastically the various methods now available for reducing piping and undue segregation. There is no question with regard to their effectiveness.

At first glance many of us have assumed that any change which would result in a 10 per cent or more greater yield from a heat of steel would result in an increment equal to the weight in question times the selling price of the steel. Thus if the daily output of a firm were 5000 tons then a 10 per cent weight saving through the use of a hot-top or similar device would mean 500 tons greater output, which at an assumed average selling price of $24 per ton would be $12,000, or on a yearly basis there would result an assumed saving of 12,000 times 300 working days or $3,600,000.

In this connection we have utterly forgotten the cost of the refinement which must include the cost of the top, the additional labor involved, the cost of the additional buildings, building sites, trackage and other items. I have no figures on these phases, but they must be considerable, amounting well over a dollar a ton in the mills best situated for this refinement. In some mills, the expansion due to normal growth, accompanied by a resultant ground congestion, has been so great that it would not be practicable to consider the use of hot-tops. In other mills this condition does not exist and plants thus advantageously located should seriously consider their use.

A striking feature of adequate discard, however, is the relative cheapness with which it can be made. These facts are brought out in the curves showing the relation of spoilage to cost increase per ton of produced billets—Fig. 3. The figures are based on the average Pittsburgh price for 1902-1906 given in "Report of the Commissioner of Corporations on the Steel Industry," Part II, dated January 22, 1912.

The prices for this period have been chosen because they will represent approximate cost figures when freight rates have been dropped to a prewar basis; a drop we are all looking for and must receive before iron and steel prices can further decline. In fact, iron and steel would be found to be

selling at a lower figure today than at many of the prewar prices if the items due to freight were neglected.

With 15.15 per cent spoilage the cost of billets is given as $18.88. Were there no spoilage the billet cost would be $17.73 per ton and of this sum the cost of the metal in the ingot form would be $16.10 per ton and the cost of converting the ingot to the billet would be $1.61 per ton. Properly chargeable therefore, as increased costs in the production of a ton of billets with a spoil-

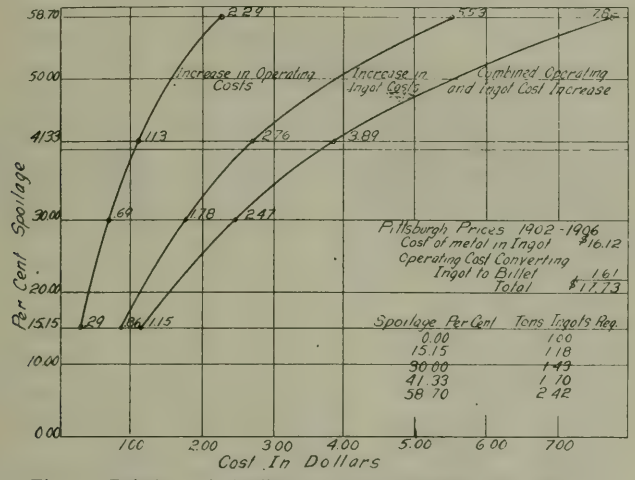


Fig. 3—Relation of Spoilage to Cost Increase Per Ton of Billets Produced

age of 15.15 per cent is 29 cents for operation and 86 cents for metal, resulting in a total cost increase of $1.15.

With a spoilage of 30 per cent the operating cost increase would be 69 cents and the metal cost increase $1.78, making a total increase of $2.47. With a spoilage of 41.33 per cent these cost increase figures become $1.13 and $2.76. A total of $3.89. With a spoilage of 58.7 per cent these figures rise to $2.29 and $5.53 resulting in a total cost increase of $7.82 per ton.

The ingot cost increase is not as striking as one might at first assume, because the actual metal loss in converting an ingot to a billet is but approximately 34 pounds. All of the remaining weight of the ingot not converted into acceptable billets is placed in a scrap class with a price value of $12.35 per ton. Thus the actual metal loss from this source is at the rate of $3.77 per ton of scrap produced.

Were it necessary for the trade to insist and the mills to produce, therefore, stock free from piping and segregation greater attention would be given to these cost figures than is the case today. Thus those firms which could keep their spoilage down to the lowest percentage, would have a distinct advantage, if the same were done at materially no increased cost, over those firms which ran into the higher spoilages.

Thus the production cost of a firm producing 1,000,000 tons of billets, with a spoilage of 58.7 per cent, would be $4,350,000, more than that of a firm with a spoilage of but 30 per cent. It is assumed that operating and raw material costs are the same. The spoilage percentages selected represent the highest and the lowest from the 40 firms to which reference has already been made. There were no outstanding refinements in the operating procedure

of any of these firms. None of them, to my knowledge, used hot-tops. None were particularly expert in the manufacture of shell stock at the time the contracts were let. The only explanation I can give for the variance in the practice is great attention to details. Details of refining practice, pouring temperature, pouring height, proper centering of the pouring stream, cleanliness of ladles and molds, proper time and temperature control for the heating of the ingots or blooms, and proper rolling practice involving proper maintenance of the rolls.

Manufacturer's Reputation Is Dependent Upon the Quality of Their Product

Good steel can only be made in the furnace; it cannot be made in a ladle in spite of what one may hear otherwise—nor can steel with proper surface be made in poorly aligned or imperfect rolls. Two years ago I was asked if alloy steel could not be rolled in a mill, the rolls in which were themselves ready for the scrap. My advice was to scrap the rolls and save the firm's reputation.

The day is not yet here when we require steel free from piping and segregation. However, is there one who will argue that such steel is undesirable? Is there one who prefers piped stock, and more especially segregated stock? Is not the trade going to demand more and more insistently stock free from defects? Are not those companies who carefully control the items leading to quality going to be in a vastly superior position to those firms that tolerate or inadequately check sloppy mill practice?

The whole problem is not an easy one. Yet for each individual firm so much is at stake, its reputation, the sale of its product, possibly its very existence, that it does seem that some of these matters should be given more careful attention than it has been my lot to observe is generally the case.

To some it may seem that the whole force of the preceding paragraphs has been nullified by the fact that certain uses of steel do not require perfect stock. It is quite agreed that there is no necessity for using a gold tack when an iron one will do as well. The trouble is, though, that those firms who base their emphasis on tonnage sell some of their stock for purposes which need careful inspection. In 1916 I saw piped shell steel discard sold for conversion into steering pins. In fairness to the steel company I believe they were uninformed with regard to the prospective use of their product. Nor do I, today, know of any automobile companies guilty of such negligence. Not only is proper discard necessary to insure freedom from piping, but also to insure freedom from segregation. In the case of segregated stock subjected to severe service such as in rails, the life of the product is much shorter, to say nothing of the hazard to life being greater, than in unsegregated stock. Stock which is to be machined should be segregated if one is to maintain good will in machine shops operating on a price basis. A bar of 0.72 per cent carbon steel mixed in with bars of 0.30 per cent carbon steel, both procured from the same ingot because of insufficient discard, can be of material weight in disrupting an organization. Items of this type have been altogether too little considered.

Primarily the procurements of piped and segregated steel lies with the purchaser. He can today, and could, even in the days of 1919 and 1920, purchase any grade of steel he desired. There were firms then and there are firms now who will state that they will furnish good steel though not inspected with sufficient thoroughness to insure freedom from piping and segre-

gation. Prices from mills of this type are usually as low, if not lower, than the prices from mills that more rigidly inspect their product. For many purposes steel of this grade is acceptable. For others it is not, although the price tempts the purchaser. Ultimate cost and essential reliability should be the criterion; not first cost.

A forward step which is sincerely desired, however, is that every mill will make a thorough-going effort to improve the quality of its steel. Practice at our various mills is not uniform. The tabulations in Fig. I demonstrate that point.

When that day breaks; when all of our mills are making steel of such high quality that a spoilage of 30 per cent would insure complete freedom from piping and segregation, and a spoilage of 15.15 per cent would insure steel of an acceptable, though not of the best, quality, we will find both consumer and producer in a mutually happy frame of mind; the consumer because of the more uniform character of his purchase and the producer because of a material reduction in complaints and because of what I believe will actually be the case, a material reduction in his manufacturing costs.

The Use of Various Kinds of Light In Metallography

(*Continued from Page* 719)

It has been found that the aforesaid only holds true where the beam of light is relatively small in comparison with the cross section of the crystal. However, if this beam is large enough to fill the back glass of the objective, it is not possible to produce a totally dark field by a rotation of the analyzer, but the phenomenon just mentioned occurs wherein the field reverses color. In the case of Figs. 4 and 6, a smaller pencil of light was used, with the result that the field is more nearly totally dark.

Conclusion

These two cases, along with numerous others, lead to the conclusion that where the beam is relatively large, only a part of the center is darkened, and the remaining light comes in around the edges as a sort of leak, so to speak, thereby obliquely illuminating the sample. From all indications, then, it would appear that this is a method of obtaining micrographs at high magnification with oblique light.

In closing there is one more point for consideration, and that is, to what limits is it practical or necessary to magnify photomicrographs. The photomicrographs shown in Figs. 8 to 13, inclusive, are all of lamellar pearlite, with the exception of Fig. 9, which is a very low carbon steel showing ferrite, ferrite grain boundaries, and a central area of lamellar pearlite. The magnifications range from 1200 to 11,000 diameters, all taken with the same objective, but with different oculars and different camera bellows extension.

The photomicrographs speak for themselves and show of what value they are in the analysis of materials microscopically. The photomicrograph shown in Fig. 13 was taken at a magnification and direct projection of 11,000 diameters, the specimen being a steel showing a structure of lamellar pearlite. When the magnification of this photomicrograph was measured, one-hundredth of a millimeter nearly filled a 5 x 7 ground glass, the long way of the glass. The value of such a photomicrograph is patent.

Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Criticism in This Column—Members Submitting Discussions Are Requested to Give Their Names and Addresses

Corrections Pertaining to Discussions Following Papers Presented at the Metallurgical Education Symposium, Detroit Convention

It is with regret that our attention has been directed to the fact that certain stenographic errors existed in the discussions following some of the papers presented at the Symposium on Metallurgical Education, Detroit convention, October, 1922, as published in the February issue of TRANSACTIONS.

In order, therefore, that any of the errors which exist may be corrected, we are reprinting several of these pages which have been reviewed by the respective authors. Our apologies for these errors are respectively extended to these gentlemen.

Pages 545-548—*February* 1923, TRANSACTIONS

Professor Knight's Contribution to the Symposium

In the school of mines at the Pennsylvania State college, we gave three curriculi; a curriculum for metallurgists, for mining engineers, and for mining geologists. The first two years is the same for all three curriculi. And we believe that there is an advantage in having the first two years the same, because, first, these years are devoted to such subjects as English, mathematics, physics, chemistry, and such fundamental subjects as are necessary as a foundation for the remaining portion of the curriculum, the last two years. And second, it gives a student a chance to study two years, and then decide what he would like to take up, whether he prefers metallurgy, mining geology, or mining engineering.

I might review briefly the last two years of our courses of metallurgy. The first semester in the junior year there are 2 credits required in physical chemistry, 2 in dynamo machinery, 1 in electrical engineering laboratory; 2 in applied mechanics; 3 in assaying; 5 credits in the principles of metallurgy, and one hour in coking. These involve laboratory as well as class room instruction. The second semester: Metallurgical analysis, 3 credits; power laboratory, 1; steam engines and boilers, 2; engineering materials, 2; testing materials, 1; metallurgy of copper, 3; metallurgy of iron and steel, 4; stresses in mine structures, and hydraulics. The senior year is devoted, the first semester to electro-metallurgy, 2 credits; electro-metallurgical laboratory, 3; principle of economics, 3 credits; economic geology, 3 credits; alloy and metallography, 4 credits; ore dressing and coal preparation, 3 credits.

The second semester of the senior year: Transportation problems; there is an option here between commerce—15, which is transportation problems, and economics—2, current economic problems or political science—13, political parties—3 credits; engineering law, which em-

bodies engineering contracts, 2 credits; metallurgy—74, advanced metallography, 3 credits; and the metallurgy of gold, silver, lead, zinc and minor metal 5½ credits; metallurgical thesis, 3 credits; and mining—78, which is the ore dressing laboratory, 1½ credits.

Now, in connection with that, I might say that an analysis of our entire curriculum shows the following results, and this is what I would like very much to have had in the form of a lantern slide for every one to see. As far as a broad general training is concerned, we try to give it. And as Mr. Knowlton was saying, any suggestions or criticisms I can obtain from anybody here, I would certainly be glad to receive. It would be impossible for you to see this on a small scale, but I would be very glad to show it to any one after the meeting. (Indicating course of study in small type). The title of this, in case you should want it is "distribution of subjects in courses in the school of mines, 1921-22, Pennsylvania State college." On this side I have the courses for the freshman, sophomore, junior and senior. Here is the semester; and above is the school in which the various subjects are taught. There is the engineering school, liberal arts, mines, natural science. Then here is a column entitled "common" and under that is "hygiene and physiology and military drill." I will summarize briefly what we have here in the metallurgical curriculum. In engineering work we have 20.3 per cent of their credits; in liberal arts, 26.68; in the school of mines, 34.32; in natural science, 13.64; in physical education, hygiene and so forth, 5.33; making 100 per cent in all.

One thing I would like to call attention to here, which is that there are only 13.64 points required in the natural science school. That is due largely to the fact that at Penn State, geology is taught in the school of mines rather than natural science which is done in a good many institutions. Likewise, mathematics is taught in the liberal arts which gives a rather high percentage, 26.68 for liberal arts, whereas it is very often included in the natural science group.

Now, I have detailed information concerning just what the various courses are during the different periods, that is, for the freshman, sophomore, junior and senior, for the metallurgist, mining geologist and mining engineers, in the table as it is worked out.

We believe in, as you will notice, 26.68 points of credit in liberal arts, and the fact I pointed out, there are the English requirements, and the requirements in economics and transportation problems, in giving as broad an education as possible. Our present curriculum is the result of a revision that has been made in the last three years. During the last three years we revised our metallurgical curriculum, and we did so by first writing to the alumni of Penn State, back as far as the graduates of 1896. We wrote to such men as Arthur G. McKee, H. M. Stuart, the superintendent of blast furnaces at Duquesne; and A. N. Neal, superintendent of the Duquesne Works, Carnegie Steel company and from then on down the rank, to the 1918 and 1919 graduates. We asked them to cooperate with us and to write in and tell us what our curriculum lacks, and what it has in it that we can eliminate. By doing that, we have the present curriculum as it is in the catalog.

I would like to call attention to something that perhaps most of you are familiar with, and that is Bulletin No. 150 of the Mining and Metallurgical Society of America; which is entitled "A Report of the Committee on Technical Education." It is by A. H. Rogers, chairman; L. C. Gratton, and A. H. Guest. They have there brought out a good many points. They

have pointed out the distribution of time on a percentage basis, devoted to different subjects in the different schools of the country. At the bottom of this, there is an average given, an average for all schools; and Penn State does not fall far from the average.

There was one thing that was mentioned in this report of the Mining and Metallurgical society, on page 183. I will just mention a word about it here. I will not take the time to read it, but I will give you the sum and substance of a part of that page. It states that the metallurgical or mining curriculum is outlined by the faculty of the mining school, and many of the subjects are taught in other schools, liberal arts, engineering and so forth; and as I have pointed out, they are very often taught with the viewpoint of making specialists in English, or specialists in economics and so on, out of the different men, rather than with the viewpoint that they are to become mining and metallurgical engineers.

We try to get around that difficulty by co-operating with the different departments of the college. We have been co-operating particularly with the chemistry department in the last few years, which was not the case several years ago. The way this is handled is that the chemistry department expects us to give a course in metallography for the special benefit of the chemist and we tell them that we will gladly comply with their request and will be glad to give a course in metallography; providing they will specify what they want taught. In the meantime we expect them to return the favor, and reciprocate by giving us courses in chemistry that will be particularly suitable to the metallurgists.

Another thing I would like to mention is that we are strongly in favor of the senior members of the teaching staff, teaching laboratory work. It is quite common in institutions for the heads of departments and men higher up on the staff to do the lecturing and conduct the recitation work, and allow student assistants and men of inferior rank to take care of the laboratory instruction. We believe that the men higher up should give instruction in the laboratory, because they are in a position to inspire the young men and work up the enthusiasm that otherwise would not be obtained. And, in a metallurgical course anyway, we believe that the real instruction comes in the laboratory, where you are really doing things.

We also believe in a thesis. We believe every student should be required to work out some problem, and submit a satisfactory thesis before graduation. We think this, because it gives the student an opportunity to show his initiative, and to show what he can do in the way of handling problems of his own. And it is a good experience for him to go after some particular problem, the like of which he may run onto, and no doubt will, when he gets out, and he then has had some experience in solving such problems. The second reason we believe this is a good thing is because it gives the instructional staff an opportunity to pick out the students who will likely make good research men. And as we know from the various research meetings which have been held in the last few years, research men are hard to find, and they are scarce.

I might add, that we have metallurgical inspection trips specified in our curriculum. The second semester of the junior year is given a four hour course in the metallurgy of iron and steel. At the close of the semester, the students are taken on a two weeks iron and steel inspection trip. During this trip all phases of ferrous metallurgy are carefully

studied. Each student is required to hand in a complete report of all operations studied.

During the second semester of the senior year, a course in nonferrous metallurgy is given. At the Easter recess period a two weeks nonferrous inspection trip is taken. Both the ferrous and nonferrous trips are planned by an instructor who accompanies the students and is in charge of the work at all times, and explains the operations observed.

The Mining society, which is affiliated with the American Institute of Mining and Metallurgical Engineers is also an important organization at Penn State. The society is composed of the faculty and students of the mining school. Meetings are frequently held at which times prominent mining and metallurgical men are secured as speakers. This brings the student in contact with practical operating men.

If a student wishes to spend five years, he is given an opportunity to study for the degree of Master of Science which may be obtained in one year after the degree of B. S. in metallurgy has been obtained provided the required amount of work is satisfactorily performed.

The degree of Metallurgical Engineer is given to four year graduates of Penn State after they have been in responsible work for at least three years and have submitted a satisfactory thesis.

Discussion of Professor Knight's Contribution

Mr. Thum: I would like to ask what was eliminated from your curriculum as a result of the questionnaire.

Prof. Knight: I am sorry I do not have all of the old catalogs which will gave this.

Mr. Thum: In general, what did you eliminate as being nonessential and what did your graduates regard as being essential?

Prof. Knight: There was one subject that we did not eliminate although there was considerable debate upon the matter, and that was the course in "stresses in mine structures." Most of the men seemed to be of the opinion that this course should not be eliminated. So that, instead of eliminating the course we made an optional between stresses in mine structures, hydraulics-1 and laboratory-3. This is one of the things that we made flexible. We eliminted 3.5 credits in surveying and 3 credits 3 credits in mining.

Another thing that we eliminated was a course in geology. The metallurgists were having a little too much geology, and we thought we could eliminate geology and put in advance metallography. Now, they have eight hours laboratory work in the second semester. If I had an old catalog, I could give you everything and would be glad to; if you are particularly interested, I can look that up and give you the whole thing in detail. Are there any other questions?

Mr. Thum: May I ask if there was anything added besides an advanced course in metallography, and if the work in economics and such allied subjects were also partly due to this questionnaire?

Prof. Knight: The work in economics I believe has been in the curriculum for a number of years, but was increased because of opinions expressed in answer to our questionnaire.

Pages 560-566—*February* 1923, TRANSACTIONS

Prof. Goodale (chairman): Is there any discussion on this paper?

Mr. Thum: Mr. Chairman, I have listened with a great deal of interest to the various addresses this afternoon. It seems to me that the tendency of modern engineering education is toward the longer course; five years and even six. Personally, I feel that such a step would be a mistake, principally because it would limit the number of students who could partake of the educational advantages of this country. It is hard enough for a great many of our good students to go for four years, but it will be very much harder to go five years, and I think that a six year course is practically out of the question.

Of course all education is good. I believe none of us would deny that a man who is educated in the liberal arts would make a better engineer than a man who merely had a high school education. I am quite sure that he would make a better engineer; in addition to that, he would make a better citizen.

Now, it might be argued that if the engineering schools are to teach engineering, they would do well to stick to engineering. By that, I do not mean of course that absolutely no attention be given to English or public speaking, but I do think that rather than extend the course of the present four years to five or six years, in order to take up humanities, it would be very much better to examine carefully the present curriculum, and see whether some of the things which are given at present could not be well substituted by other courses.

I have traveled around more or less in the last four years and visited many of our prominent technical schools and before that time I had the honor to be a member of the faculty of the University of Cincinnati. My present information is to the effect that most of the metallurgical courses at present offered in this country are hybrids; they are merely slight adaptations of mining engineering. Of course, there is an historical basis for that.

When I was a boy, heat treatment was practically unknown. The modern large smelter and manufacturing plant was unknown. Most of the ore smelting was done close by the mine. Things have changed in 30 years; and perhaps in 30 more years the universities will come to the conclusion that they had better do something about it. I speak advisedly because, having been a member of a university faculty, and of a school not so backward at that, I would like to stake the ordinary university against anything in this world when it comes to sheer inertia. They will get around to it after while, but it seems it is a long time coming.

Again reverting to the fact that metallurgical engineering is more or less the same as mining engineering, I would like to ask why the metallurgist should be asked to take mining surveying, for instance or mining engineering. The metallurgist is not particularly interested in the long wall versus the pillar and room method of coal mining, or the square-set methods they use for timbering stopes, or the steam shovel methods used in the iron country, and yet he in a great many cases has to take that as a prerequisite for his graduation. It seems to me that since there is a great demand for the humanities, it would be very well, indeed, to go after some of these so-called metallurgical subjects with a sharp broad-axe, and cut out some of these things which they have had for the

last few years, and which have not the remotest connection to the technical end of metallurgy as we understand it at the present time.

Of course, in order to revise and re-vamp a course of study, you would have to define metallurgy. That would be a difficult thing to do. But, if you agree with me that it involves the preparation of a metal from its ore, the preparation of alloys from the metals and the properties and heat treatment of these metals and alloys—from such a definition of that sort, or a more perfect one, it would be comparatively easy to get a curriculum which would be restricted to that field more or less closely, and would devote any extra time to such things as English, public speaking, history, economics if you will and some of the other things in literature and art which are supposed to make an engineer a good citizen.

Now, it has been brought out, and I think very well, that the fundamentals should be taught rather than the specialties. No university can turn out a specialist. In the first place, they have not the equipment; in the second place they have not the teachers. The best they can do is to ground a man in the fundamentals. And I think that metallurgy could be taught very well from that standpoint. In the preparation of the metal from its ore, you have several fundamental operations, roasting, smelting and refining. The fundamentals of roasting are much the same whether you are roasting the ore and producing sulphuric acid as a by-product, or whether you are roasting a relatively small amount of sulphur from an iron ore. There is a great deal in common in the blowing of bessemer steel, copper matte and open hearth refining of pig iron. And so when the students get over into the alloys, they should have physical chemistry and physical metallurgy as fundamentals. In that connection a great deal could be done for our young students and as far as I know, it is seldom being done in this country, in teaching them the practical end of alloying; for example, how to make a brass casting that does not look like a sponge. Then, going on further they would enter the broad fields of heat treatment, hardening, carburization and what not, which applies not only to steel, but to a great part of aluminum and copper alloys as well. It would always be well to teach these things from their broad aspects, to show the pupils the underlying generalities, rather than to lose them in a wilderness of facts.

Given, finally, a modern curriculum on metallurgy, you come right back to one of the great questions. It is not *how* you teach, or *why* you teach, but it is the *teacher himself* that counts for the most. I personally am a great believer in the idea that the student gets the most value out of university training from his instructors and from his fellow students. By all odds, that was the greatest thing in my own university life; and observations of other chaps since that time has only confirmed that belief. The prime thing about university life to make a good citizen, to make a good engineer, is to give him the right kind of instructors, men he can look up to; and then give him the right kind of associates, the right kind of surroundings, and great things will result.

Now, unfortunately,—I rather venture on this with some temerity, in view of many good friends in the teaching profession here—unfortunately, we haven't as yet the right kind of men teaching metallurgy. I feel that we will not get those men until some of the big business men in the steel, copper and the other metallurgical industries,

realize that in view of the importance of metallurgy, the attention and financial support which they are giving to metallurgical engineering is shameful. There is no other word for it. We have tremendous foundations and endowments in medicine and law, and whatnot; and yet here is a fundamental industry of our country, which enables us to produce more metals and metal products than any other country in the world, and yet we have no organized effort in the industry for the teaching of the men who are to carry that work forward. Until the industry realizes that fact, until the university can properly endow the laboratories and properly endow the chairs, so that they can go out into the industry and compete for the right metallurgists and put them in the right place, I am afraid metallurgical education in this country is going to be backward.

Prof. Boylston: Mr. Chairman, there is one remark I would like to make here. Mr. Thum spoke about the course in mine surveying that we give the metallurgist. He mentioned that specifically so I think I ought to say something about it. I believe that is one of the courses that does more to humanize the student than perhaps any other course in our school. They go down to camp for about four weeks, after proper class-room instruction, so that they may know how to use the instruments, they climb around in the muck and they live out of doors for a month, in association with their companions and with their instructors, and they have a nice rough time of it, and they learn a good deal more than mine surveying as it is mapped out on paper. I think that is a real humanizing course; that is so in our school anyway.

Prof. Demorest: There is one thing that I would like to add. One of our number just touched upon the tendency everywhere for engineering schools to require some practical experience from the men before they graduate. In our course in metallurgy, at Ohio State university, a man cannot get his degree until he has had one whole summer, at least in practical work in this line. Then he has to come back, with a properly certified letter concerning his work from his employer; and the teacher checks up in other ways on that man. In addition to that, we have inspection trips, as Prof. Boylston's slide shows you. So that there is a good deal of the practical touch in the course,—as much as can be made possible.

Prof. Upthegrove: While I agree with Mr. Thum in many ways, I would like to point out that our work at the University of Michigan is not the outgrowth of a mining engineering course, but of chemical engineering. We have one mining engineer of whom we are exceedingly proud, Mr. Brush of Cleveland, who was granted the degree of Mining Engineer by the University of Michigan. (I believe I am correct in the statement that Mr. Brush received the degree of Mining Engineer.)

Our course does not carry many of the subjects to which Mr. Thum referred, but it carries certain fundamental chemical engineering courses. We believe a metallurgist should have a fundamental training in chemical engineering. Our course has not developed as far in metallurgical work as we should like. We should like to have it include certain things along the lines on which Mr. Boylston spoke. Our metallurgical work starts in on the extractive basis, and follows with a certain amount of work on fabrication. We are attempting, although not to any great

extent, but just starting in along another line that Mr. Thum mentions, to show a man how to produce what you would call a "finished casting." That is a little in the distance as yet, but it is a line along which we are working at the University of Michigan. The nature of our course is probably due to the fact that we were not connected with a mining engineering course to begin with, but that the metallurgical work is the outgrowth of chemical engineering.

Prof. Boylston: I would like to add that in Cleveland we teach our boys in the technical high schools how to mold and do certain other foundry operations. We do not believe that the college grade of school should teach trades or the art of any particular metallurgical process from the point of view of the art itself. We also are trying to teach fundamentals. We may not have the same idea as some others as to what the fundamentals consist of but we are trying to teach fundamentals, not art. That seems to be a necessity. I do not know where you can get the principles outside of a college course, except in the school of bitter experience. Taken by and large, our courses are planned from the standpoint of principles rather than practice.

Mr. Thum: Just a word more. I would be extremely sorry if any of the remarks I have made were taken in a purely personal way by any of the men here either against them or their institutions. I tried to make them general; and the general ideas, which I so very poorly expressed, were that we yet have to approach metallurgical education as a unit itself and not as a hybrid; and second, the metallurgical industry is not supporting metallurgical education as it should.

Mr. McKnight: Speaking entirely from my own very brief experience, I would say that the education of the metallurgist could be divided up to include four phases, that of the fundamentals (which have been spoken about) breadth, balance and co-ordination.

It is necessary to dwell long on fundamentals. It is almost axiomatic that an engineer cannot go into the higher studies unless he understands elementary chemistry and physics and mathematics.

As far as breadth is concerned, I think that the subject of specialization can be carried too far. If a man could look ahead 50 years and see that all of that time he is going to be engaged in the production of steel by the open-hearth process, eventually arriving at the position of open-hearth superintendent, at which job he would stay, it would be very easy to teach that man how to produce steel by the open-hearth process; and you could then specialize. But, when a man leaves college, he does not know whether he is going to be a heat treater, an open-hearth superintendent, or in any other particular kind of work. He may change into five or six different lines of work. Therefore, I think it is very proper that the colleges should keep their courses as broad as possible. It should not be carried to the extreme. I was thinking of a moment ago where one of the colleges had a man who was pretty good in football. He flunked the course in ancient history, and the professor tried to coach him through that course, but he seemed to be bent on fouling it, so that finally the professor gave it up in despair. The man had to play the next day, so the professor said "answer one question, and I will let you out." He asked him, "who dragged whom around the walls of what, how many times, and why?" And he could not answer the question.

The next point is balance. That is best illustrated in my opinion by a brother of mine who was graduated from a well known eastern university, intending to go into the steel business. In his senior year, he studied Italian literature, Spanish history, political economy, accounting, and field artillery. I think that is what you would call a case of very poor balance in a man's education. It seems to me that he had a very poor balance between what has been termed here the humanizing elements of the course, and the more technical elements. There is a dividing line.

The fourth point—that of co-ordination—is mentioned because I think there are so many students who study metallurgy and get out in the world as metallurgists with unco-ordinated facts. As an example, take the boy who studies the metallurgy of steel at one time in his college course, mechanics of materials at another and heat treatment and metallography at others. He must learn from practical experience the relation of these subjects. To remedy this situation, a student might be given a piece of steel of standard analysis and be required to analyze it, to pull a test piece, to examine it under the microscope and to heat treat it. If this were consistently done, the facts learned would be of real value to the student.

Prof. Boylston: Mr. Chairman, may I say that our so-called thesis work is planned with the idea of co-ordinating all of the previous courses.

Of course, we do not have as much time to do it as we would like to, but our men have five afternoons a week, of about three hours each, and as much extra time as they can cram in for half a year with just that purpose in mind.

I would rather they would learn how to do that, rather than get any actual results, that is, results of value for publication, or anything of that sort.

Prof. Demorest: I might add one thing along that line, and I think it is going to be very effective in our course in metallurgy, and that is running throughout the last two quarters of the senior year we have a course called "metallurgical investigations," in which the class is divided up into perhaps three sections and maybe four, depending upon the type of men we have; and each section then takes a subject, and under the direction of the instructor carries out a complete line of investigation. That is entirely different from his thesis which he has to carry on his own accord. Then the other section of the class carries out an investigation under the direct supervision of the instructors. That has been found very valuable and particularly effective in other work, and we have taken it over in metallurgy. It may be useful to others.

Mr. Wood: There is one point about the fifth year which I wish to mention. It has been said that it would not be possible in many cases to send the boy to school five years; that it is hard enough to send him for four years. Actually, this does not present much difficulty because in a great many cases there are assistantships and fellowships open to students that make possible the fifth year at college. In many cases one finds that this happens: A man will graduate, go out and take a position. After a short time, problems will come up which show him that a fifth year at college would be very useful and he makes arrangements to come back and stay the fifth year. Once in a while the plant

for which he is working will give him financial assistance. I believe there is a distinct tendency toward a five year course and that the financial question is not difficult to solve.

Prof. Boylston: Mr. Chairman, may I say just a word on that? It seems to me it makes a difference in the case of the fifth year whether you are going to prescribe it as a part of the required course, or whether you make the fifth year optional with those who can afford to take it. My choice would be to have an optional fifth year, lay out an optional course for the students, and allow those who have the additional time and means to take it. In most colleges it is handled through the graduate school and we are doing this now. This is quite a different matter than to have a five year required course as some schools do.

Prof. Goodale (chairman): I might say, from my own experience, that our curriculum, in both the mining and metallurgical engineering courses, is under almost constant revision—I have sometimes thought too much so—because we hardly get the curriculum on one basis in working order before we get a suggestion from some source or the other, where they think we can make it better and changes are made. In that way we attempt to make the curriculum as effective as we can, so that the men we turn out will make good in the industry. We are very much on our toes toward that end, and we are in close touch with the great steel industry in Pittsburgh and in close touch with our alumni, so many of them finding work nearby, that I feel we are in an exceptionally favorable situation to learn what is needed.

I am sure that we can go on almost indefinitely and have others outline their experiences and their ideas. I feel that I owe an apology to the speakers who have favored us so far. Most chairmen of meetings will say more in words of appreciation of the speakers than I have; but I have not done so merely to save time on the program. It seems to me that each man has brought up a great deal that is well worthy of the attention of us all.

We have a short written contribution from Huge P. Tiemann of the Carnegie Steel company and another one from B. H. DeLong, of the Carpenter Steel Co.

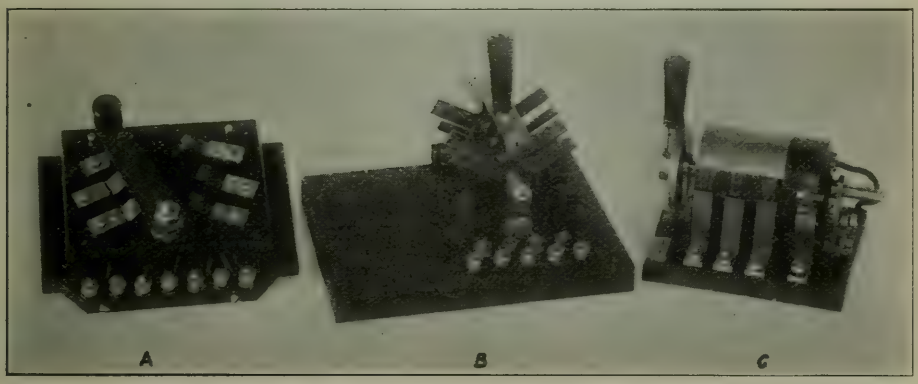


Fig. 7—Special switches used with the recording chronograph described by H. J. French, physicist with the Bureau of Standards, in March TRANSACTIONS and referred to on page 647.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

NEW QUESTIONS

QUESTION NO. 76. Why are cold drawn carbon and high-speed steels sometimes supplied with a copper coating? Does this coating affect the steel in any way, or is it merely a lubricating agent in the drawing process? Is it necessary or desirable to remove the coating before hardening?

QUESTION NO. 77. What is meant by the terms, elastic limit, yield point and ultimate load?

ANSWERS TO OLD QUESTIONS

QUESTION NO. 27. What is the function of the high phosphorus and the high sulphur content in the so-called automatic screw stock steel?

QUESTION NO. 59. Is a sulphur content of 0.067 per cent detrimental to the proper carburizing of a low carbon steel having a low manganese and phosphorus content?

QUESTION NO. 64. To what extent can the deep etching of specimens of steel be applied to routine examination of incoming material?

QUESTION NO. 66. What method and procedure is used in brazing stellite to carbon steel?

ANSWER. The method and procedure in welding or brazing stellite to carbon steel is covered rather fully on pages 49 to 52 of the Haynes Stellite Company's publication, "Stellite Reference Library," Volume 9.

QUESTION NO. 67. What is the reason for the fact that a piece of steel quenched in brine will be harder than the same piece of steel would be if quenched in water, providing that the quenching temperatures and quenching medium temperatures are the same in each case?

QUESTION NO. 68. What is the correct temperature of heating for forging a .40-.50 per cent carbon steel into automobile crankshafts?

ANSWER. By Harold F. Wood, metallurgist with the Ingalls-Shepard Division of the Wyman-Gordon Co., Harvey, Ill.

It has been our experience that the proper forging temperature for forging .40 to .50 percent carbon steel for automobile crank shafts is from 2000 to 2100 degrees Fahr. We find that on most heats of steel this temperature can be increased to 2200 degrees Fahr., but in no case must it be allowed to exceed 2200 degrees Fahr. The safe working temperature is to be at all times kept under 2100 degrees Fahr. We have made hundreds of tests and are thoroughly satisfied that these temperatures are correct.

QUESTION NO. 69. Is sulphur up to .10 per cent detrimental to the quality and physical properties of an automotive steel?

QUESTION NO. 70. Is it possible to have a specimen of steel in such a condition that it will show in any one field observed under a microscope at 100 diameters magnification, ferrite, pearlite, sorbite, troostite and cementite?

ANSWER. By H. M. Boylston, professor of metallurgy, Case School of Applied Science, Cleveland, Ohio.

I have never observed in a single specimen the combination of metallographic constituents mentioned in the above question, although I suppose it might be possible to obtain it by quenching in water while the steel was

passing through the critical range, a steel let us say with 1 percent carbon which had been previously annealed to produce spheroidized cementite on a ferrite back ground.

A number of times I have produced a combination of pearlite, sorbite, troostite and martensite in the same specimen, by quenching an .80 or 1.10

per cent carbon steel while it was passing through the $Ac_{3.2.1}$ transformation the steel having previously been in a pearlitic condition.

The accompanying photomicrograph shows a combination of four constituents taken from a steel containing about .80 percent carbon and magnified 100 diameters. The white constituent is martensite, the darkest constiuent troostite, certain half-tone regions sorbite and the light gray regions pearlite. The pearlite and sorbite merge into each other but there is generally a distinct line of demarkation between the troostite and sorbite on the one hand and troostite and martensite on the other.

QUESTION NO. 71. How do the physical properties compare between a 0.35-0.45 per cent carbon acid open-hearth steel and an alloy steel of either 3.5 per cent nickel or 1.5 per cent nickel and 0.50 per cent chromium neither heat treated?

QUESTION NO. 72. What elements are conducive to good electric butt-welding of steels?

QUESTION NO 73. Does electric butt-welding destroy the physical properties developed in a steel which has been heat treated prior to the welding operation?

QUESTION NO. 74. Why shouldn't a bar of steel rolled from a locomotive axle be better than one rolled direct from the billet made from the original ingot?

QUESTION NO. 75. How much would the cold drawing of any steel affect its hardness when only one or two, light passes are given for the purpose of sizing only?

ANSWER. A piece of 1-inch round 1.00 per cent carbon tool steel drawn with a 0.028 to 0.031-inch reduction will show 8 to 12 points higher Brinell number than the annealed section from which it is made. It is impossible to lay down a definite rule covering all sizes, grades and percentage of reduction.

A small section of chrome-nickel steel, annealed, showed a Brinell number of 121 and the same section after a 1/32-inch reduction showed a Brinell number of 156.

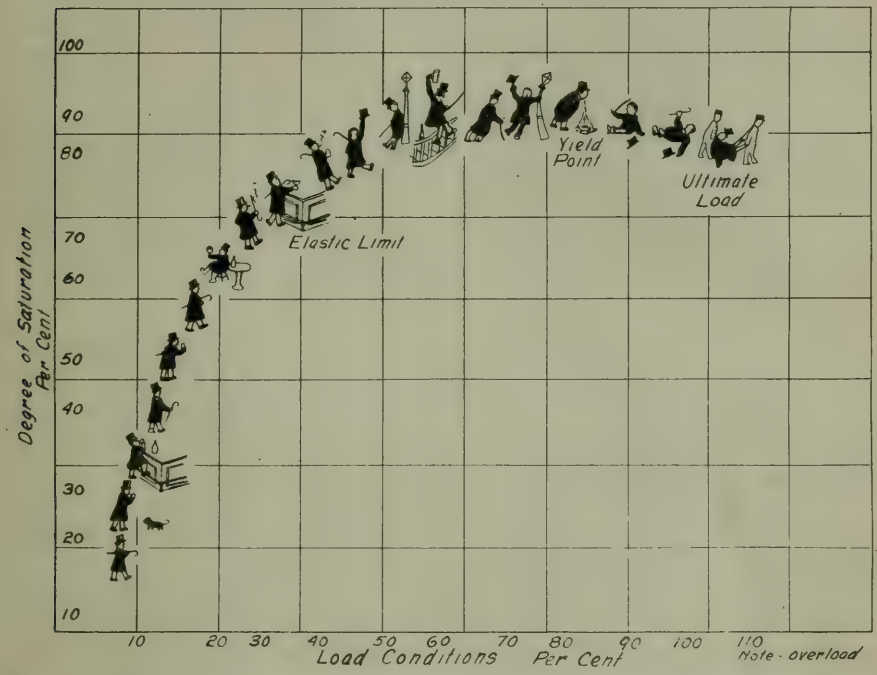
A piece of high-speed steel 0.768 × 0.383 inches, annealed, showed a Brinell number of 207, and the same section after 0.012-inch reduction showed a Brinell number of 212.

QUESTION NO. 77. What is meant by the terms, elastic limit, yield point and ultimate load?

ANSWER. The accompanying chart undoubtedly defines these terms

more clearly than could mere words. Of course there are other definitions which from a technical view point would be quite different, however, this is someone's visual or graphic interpretation.

As the author of this chart is unknown to us we regret that we cannot



give him the proper credit. Nevertheless, full credit is acknowledged to him to whom credit is due. Perhaps the author will be just as well satisfied that his name does not appear in print.

Reviews of Recent Patents

1,434,395. Electric Furnace. William Meinersmann, Elizabeth, N. J., assignor to Metal and Thermit Corp., Chrome, N. J.

This patent covers an electric furnace which is a combination of a roof, a hearth, a means for charging said furnace with a metal and means for withdrawing said metal and slag. There are one or more fixed electrodes associated with said furnace, one or more moving metal electrodes formed of compressed scrap metal and associated with said furnace. There are provided electrical connecting means between said moving electrodes and said fixed electrodes; this said connecting means forming the secondary circuit of the transformer and in addition a means for supplying an alternating current to the primary circuit of said transformer.

1,434,484. Process of Producing Iron. Donald M. Crist, Santa Cruz, Cal.

The process of producing iron from iron oxide which comprises heating the oxide in a closed retort to a temperature sufficiently high to dissociate the oxide, removing air and liberated oxygen from contact with the heated mass and cooling the mass out of contact with oxygen.

1,435,294. Manufacture of Steel. Robert Abbott Hadfield, Westminster, England.

Describes a steel alloy containing from about 2 per cent and upwards of manganese, from about 0.7 per cent up to about 2 per cent of carbon, a substantial amount of copper, and from 0.1 per cent and upwards of silicon.

1,435,304. Reverberatory Furnace. Archie Noel Jette, Anaconda, Mont.

This patent covers a furnace of the type described; the combination with the roof, a feed pipe extending therethrough and a solid metallic body containing a cooling coil surrounding the pipe.

1,435,742. Production of Refractory Metal Alloys. Byramji D. Saklatwalla and Arthur N. Anderson, Clarton, Pa., assignors to Vanadium Corp. of America, Bridgeville, Pa.

This patent describes a method which consists of feeding a mixture containing a vanadium-bearing material, a fluxing material, and carbonaceous material directly into the high temperature reaction zone of an electric smelting furnace.

1,435,812. Electric Spot-Welding Machine. F. M. Cushing and W. L. B. Cushing, Los Angeles, Calif.

A spot welding apparatus comprising a frame, chambers carried upon the frame and having offset portions extending into juxtaposition. A means to produce a circulation of a cooling medium within the chambers in contact with the cooling medium, and electrodes carried by the holders at points adjacent to the offsets of the chambers are described.

1,435,840. Manufacture of Steel. Robert Abbott Hadfield, Westminster, England.

Describes a manganese steel with about 1 to 4 per cent of copper.

1,435,991. Combination Gas and Oil Burner. W. W. Stevenson and O. H. Bathgate, Wilkinsburg, Pa., assignors to Anthony Company, Long Island City, N. Y.

A fuel burner having a liquid fuel duct within the burner, a spray plug at the outlet end of the said fuel duct, a gas chamber surrounding the said duct, and a means to discharge either liquid fuel or gas at the outlet end of the burner. In addition it has an air supply connection to the burner, an adjustable annular air passage at the outlet end of the burner, with the said passage being so shaped and located as to create a partial vacuum directly beyond the gas chamber while air is being forced through the said air passage. The outlets of the said air passage and the said gas chamber are located at some distance beyond the spray plug.

1,436,497. Electrode Furnace. J. H. Gray, N. Y. C.

This patent describes a combination with a tilting electric furnace of an electrode adjusting mechanism for said furnace with said mechanism comprising a motor mounted independently of the furnace and a flexible connection extending from said motor to the electrode. One part of the said connection extends from the motor to a member mounted on the furnace and engaging said member at a point which is substantially unchanged when the furnace is tilted and another part of the said connection extending from said point of engagement to the electrode, whereby the latter is held in substantially the same position with reference to the furnace when the furnace is tilted as when it is upright.

1,437,273. Manufacture of Ferrous Alloys. H. A. Skelley and A. B. Smith, Battersea, London, England, assignors to Continuous Reaction Co., Ltd., London, England.

This patent covers the manufacture of an alloy, containing iron and chromuim, by the silico-thermic reduction of iron oxide and chromiferous material in the presence of an oxidizing agent containing nitrogen.

1,437,405. Method and Means of Treating Molten Metal. F. L. Driver, Jr., Newark, N. J., assignor to Driver-Harris Co., Harrison, N. J.

A process of treating molten alloys adapted to be cleansed by magnesium, the improvement which consists in alloying magnesium with a heavier metal, the magnesium being approximately 50 per cent of the resultant product, and combining the resultant product with the molten alloy.

1,437,584. Refractory Material for High-Temperature Apparatus. H. B. Clapp, Battersea Park Rd., London, England, assignor to Ferolite Limited, London, England.

A refractory material for high temperature apparatus comprising a mixture of chromite and ferro-silicon reduced to small particles and mixed with a binding agent.

1,438,342. Reverberatory Furnace. W. F. Sklenar, London, England.

This patent covers a reverberatory melting furnace comprising a metal casing, a frame supporting said casing, and a lining of fire bricks arranged within said casing to form (1) a working bed with vaulted roof constituting a work chamber (2) an enclosed combustion chamber or fire place (3) a fire bridge (4) an up take and metal feeding hopper at the opposite end to the fire place, and (5) a restricted passage forming a communication between said hopper and working chamber. An inlet for compressed air opening into the combustion chamber beneath the fire bars of the grate, charging holes in the roof for fuel and metal as well as inspection and tapping holes in the side wall of the furnace are provided in this patent.

1,438,381. Electric Reverberatory Furnace. R. M. Keeney, Denver, Col.

This patent describes an electric smelting furnace comprising a smelting chamber, a settling chamber, and a passage narrower than the first-mentioned chamber, by which melted matter and gases of combustion produced in the smelting chamber may freely enter the settling chamber. Electric heating means establishing a determinate melting zone on the floor of the smelting chamber, in line with said passage, and a means for feeding material laterally into said zone are provided. The smelting chamber has a flue opening for the escape of gases of combustion and an opening for the outflow of melted matter below the upper level of said passage.

1,439,409. Tilting Furnace. J. A. Gaskill, Cleveland, O.

This patent describes a tilting furnace having in combination a melting chamber, an annular chamber for hot air encircling the melting chamber, and trunnions upon which said annular air chamber and melting chamber are pivotally supported. The supports for said trunnions and burners in said trunnions discharge tangentially to the walls of said melting chamber. Each burner comprises an elongated commingling tube open at its inner end, and a nozzle for fuel oil spaced from the inner end of said commingling tube, and a passage for air under pressure in each trunnion. Each of these passages communicates with said annular air chamber and the passages lead from said annular air chamber to said commingling tubes in the trunnions. The air supply pipes communicate with the air passages in the trunnions and the fuel oil supply pipes enter the annular air chamber through the trunnions and traverse the annular air chamber. In addition to traversing the air passages leading to the commingling tubes, the oil pipes communicate with the nozzles in the commingling tubes.

1,439,410. Refractory Material And Furnace Wall Built Thereof. J. H. Gray, New York City.

This patent covers a furnace wall comprising a body of carbonaceous material and an inside exposed facing of another refractory material which has a higher resistance to oxidation.

In addition this patent covers a brick for building furnaces comprising a body of carbonaceous material and a face of another refractory material which has a higher resistance to oxidation.

1,439,939. Low-Percentage Manganese Steel. F. M. Blake, Chicago Heights, Ill., assignor to American Manganese Steel Co., Chicago, Ill.

A commercial steel containing manganese and carbon in the proportions of about 4.25 per cent manganese and 0.42 per cent of carbon.

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

SERVICE FOR MEMBERS

The Library Bureau of the American Society for Steel Treating is operated to give to the members quickly, reliably and at the minimum expense the following service:

1. A complete copy of the magazine article referred to in any periodical you may be reading.
2. A translation of foreign articles that would help you with your work.
3. A list of references to books and articles on any metallurgical subject.
4. Informing the members of new articles of interest to them as an engineer.

The Library Bureau makes the entire field of literature available to every member, distance is eliminated, for it will copy the desired information and send it to you. It also helps the busy man by supplying information without any expenditure of his time. The charge for this personal work is merely its cost.

The Library Service does not obtain any profit from the work, but does this to make the information contained in the large libraries with which it has connection available to every member. The rates are as follows:

Photo Print Copies of articles, drawings, etc., 25c per 10 x 14-inch sheets.
Searches, abstracts, etc., $2.00 an hour.
Translations, $6.00 per thousand words for French of German; $7.50 and upward for other languages.
Reference card service, giving reference to current magazine articles, $10.00 a year in advance, and 5c for each card mailed.

Members desiring to avail themselves of this service should address Library Bureau, American Society for Steel Treating, 4600 Prospect Ave., Cleveland, Ohio.

THE CHARACTERISTIC CURVES OF A NICKEL STEEL AND A CHROME STEEL. By H. Jungbluth, in *Stahl and Eisen,* Vol. 42, page 1392, 1922.

The hardness obtained in a nickel or chrome steel depends on the temperature of quenching and the rate of quenching. Curves of the maximum hardness which can only be obtained by certain combinations of quenching temperature and rate as shown when the steel is quenched from a higher temperature it is softer because of the presence of austenite; if from a lower temperature it is softer because of pearlite formation. For every steel a set of curves of equal hardness may be drawn with rate of cooling and quenching temperature as co-ordinates. These are the so-called characteristic curves for the steel. They are given for a steel of 0.5 per cent C, 5.0 per cent Ni and for a steel of 1.6 per cent C., 1.6 per cent Cr.

THE FLOW OF METAL DURING FORGING. By H. F. Massey, in *Forging and Heat Treating,* February, 1923, page 122.

This is the second part of a paper presented at a session of the Manchester Association of Engineers, Manchester, Eng., dealing with a discussion of the flow of metal when forged in the hot state. The author discusses the forging of metals by the pressing versus the hammering methods and summarizes his deductions into ten main divisions.

BRITISH PRACTICE IN HIGH-SPEED STEEL. By H. K. Ogilvie, Alfred Herbert, Ltd., Edgewick Works, Coventry, England, in *Iron Age,* March 8, 1923, page 679.

The above article has been taken from a paper presented at the September (1922) meeting of the Iron and Steel Institute in London, England, and gives some phases in the manufacture and heat treatment of high-speed steel. It also compares electric and crucible processes, and describes the hardening method as used by the British.

ALLOY STEEL FOR STRUCTURAL PURPOSES. In January 25, 1923 issue of *Iron Age,* page 281.

The above has been taken from a paper entitled "The Study of Steels for Engineering Structures" by Dr. Geo. K. Burgess, U. S. Bureau of Standards. It compares the use of nickel, nickel-chrome and silicon steel in constructing bridges. The possibilities of copper as an alloy is also discussed. It also states that there are possible uses of heat-treated steels in engineering structures.

DIE-SINKING UNDER A DROP-HAMMER. By Fred H. Colvin, in *American Machinist,* March 22, 1923, page 449.

The author in discussing this method states that it is one which saves time and is economical in helping to reduce the cost of die-castings.

DEFECTS IN STEEL INGOTS AND CASTINGS. By O. A. Knight, in *Forging and Heat Treating,* February, 1923, page 98.

This paper contains a comprehensive discussion of the common defects in ingots and castings including cracks, pipes, blow holes, non-metallc inclusions, coarse crystallization and segregation. The author shows by means of sketches the manner in which ingots of various shapes solidify. He likewise shows the manner in which pipes and cavities occur and how they may be materially reduced.

SCREW MACHINE PRODUCTS MADE IN LESS THAN THREE SECONDS. By Luther D. Burlingame, industrial superintendent, Brown & Sharpe Mfg. Co., Providence, R. I., in March, 1923, *Machinery,* page 507.

The author gives examples showing how rapid production can be obtained by careful tooling and machine timing.

METALS USED FOR DIE-CASTINGS. By A. G. Carman, Franklin Die-Casting Corporation, in *Machinery,* March 1923, page 516.

The above article states that the zinc-base metals and aluminum alloys as well as babbitts are the principal ones used for die-castings. There are specifications included giving the limits of weight and accuracy for die-castings made from the different metals.

(*Continued on Page* 792)

News of the Chapters

SCHEDULED REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Boston—Second Tuesday
Bridgeport—Thursday between 20th and end of month
Chicago—Second Thursday
Cincinnati—Second Thursday
Cleveland—Fourth Friday, Cleveland Engineering Society Rooms, Hotel Winton; meeting at 8:00 p. m.
Detroit—Second and fourth Monday, Wing E., 15th Floor General Motors building.
Hartford—Friday nearest 10th of month
Indianapolis—Second Monday
Lehigh Valley—No regular night
New Haven—Third Friday
New York—Third Wednesday
Philadelphia—Last Friday
Pittsburgh—First Tuesday
Providence—No regular night. Nov. 10th, Dec. 12th.
Schenectady—Third Tuesday
Springfield—Third Friday
South Bend—Second Wednesday
St. Louis—Third Monday
Syracuse—No regular night
Tri City—Thursday
Washington—Third Friday
Rockford—Second Friday following the second Thursday

MEMBERSHIP AND ATTENDANCE CONTEST

The contest is becoming very interesting and quite rapid rearrangements are being made as some of the chapters have their machinery well oiled so that it is now in excellent working condition. It is interesting to note that four chapters have had an increase of over 50 per cent since the beginning of the contest and that for the first time Detroit is not holding position No. 1 in membership gain since Sept. 1, being 0.8 per cent below Tri City. The following arrangement of the chapters shows the percentage of net

increase of new members as of March 1 based on the number of members each chapter had on Sept. 1, 1922:

	Per Cent		Per Cent		Per Cent
1. Tri City	61.0	10. Lehigh Valley	26.8	19. Chicago	15.0
2. Detroit	60.2	11. Cincinnati	26.7	20. Washington	15.0
3. South Bend	60.0	12. Buffalo	22.5	21. Indianapolis	14.3
4. North West	52.2	13. Cleveland	20.8	22. Pittsburgh	12.2
5. Philadelphia	42.7	14. New York	20.2	23. St. Louis	10.5
6. Boston	39.4	15. New Haven	18.2	24. Springfield	10.3
7. Milwaukee	37.0	16. Toronto	17.9	25. Worcester	8.9
8. Syracuse	32.8	17. Hartford	17.8	26. Providence	0.
9. Schenectady	29.4	18. Rockford	16.7	27. Rochester	0.

Attendance at February Meetings

Only 17 chapters reported attendance at the February meeting and there are other chapter meetings, reports of which have not yet reached the office due to the fact that they were held the latter part of the month. Four chapters showed over 50 per cent of their membership in attendance, while Providence showed an attendance of 75 per cent, which is the highest percentage any chapter has shown in the contest. The following gives the percentage of attendance at the February meeting of the chapters reporting. Those printed in CAPS show an increase in percentage of attendance:

	Per Cent		Per Cent		Per Cent
1. PROVIDENCE	75.0	7. North West	39.6	13. St. Louis	25.0
2. SYRACUSE	59.0	8. PHILADELPHIA	33.6	14. Cleveland	21.6
3. TRI CITY	56.8	9. HARTFORD	33.3	15. Cincinnati	21.4
4. SOUTH BEND	51.5	10. Schenectady	31.7	16. Detroit	19.1
5. ROCKFORD	44.2	11. Indianapolis	27.3	17. Pittsburgh	14.7
6. MILWAUKEE	41.3	12. Boston	25.0		

Standing of the Chapters in Contest

In order to determine the standing of each chapter in the contest, it is necessary to add the percentage of attendance at the December, January and February meetings and divide by 3 to determine the average attendance for the three meetings. The average thus obtained is added to the percentage of net increase obtained since Sept. 1, 1922, to Feb. 28, 1923. This total is then divided by 2 to obtain the standing of each chapter in the contest inasmuch as attendance counts 50 per cent and increase in membership 50 per cent. On this basis we find the following to be the standing of the chapters on March 1 in the membership and attendance contest:

	Per Cent		Per Cent		Per Cent
1. South Bend	55.5	9. New Haven	31.0	17. Cleveland	22.0
2. Tri City	53.5	10. Rockford	30.8	18. St. Louis	21.2
3. North West	46.8	11. Toronto	30.6	19. Indianapolis	20.8
4. Detroit	41.7	12. Schenectady	30.5	20. Chicago	19.5
5. Syracuse	41.4	13. Providence	30.3	21. Washington	17.9
6. Philadelphia	37.4	14. Cincinnati	26.1	22. New York	17.5
7. Wilwaukee	33.5	15. Hartford	25.6	23. Pittsburgh	14.1
8. Boston	32.2	16. Springfield	22.3		

New Members

There were 86 new members added to the rolls during the month of February which is a very remarkable record when you consider that it was a short month. However, "there must be some bitter with the sweet"

and in this instance, the bitter is the fact that 39 members of various chapters were dropped for nonpayment of dues. These names have been listed on the monthly report to the secretary and chairman and in most instances the neglect to pay dues is an oversight. Here is an excellent opportunity for the local executive committee to give some personal attention to these members and get them to continue their membership.

In addition to the 39 members dropped from the rolls 14 resignations were received making a total loss for the month of 53 members, leaving a net gain of 33.

Based on the number of members in each chapter on March 1 the following table shows the standing of the 27 chapters of the society. Those printed in CAPS have advanced their positions, while those in *italics* have a lower position than that occupied in the report printed in March TRANSACTIONS:

1. Detroit
2. Chicago
3. Pittsburgh
4. Philadelphia
5. Cleveland
6. New York
7. Hartford
8. Boston
9. Milwaukee
10. SYRACUSE
11. *Lehigh Valley*
12. *North West*
13. TRI CITY
14. *Worcester*
15. St. Louis
16. **Indianapolis*
17. **Rockford*
18. CINCINNATI

*Tied.

19. *Washington*
20. Buffalo
21. Schenectady
22. SOUTH BEND
23. *Springfield*
24. *Providence*
25. New Haven
26. Toronto
27. Rochester

CHICAGO CHAPTER

The regular meeting of the Chicago chapter was held at the City club on Thursday evening, March 8th.

Professor H. F. Moore, of the University of Illinois gave the members a very interesting talk on: "What We Know About the Fatigue of Metals and What We Do Not Know."

This was the third meeting at which Professor Moore presented a paper before the Chicago chapter, and as evidenced by the fact that 115 members and guests were present at this meeting, the members of the Chicago chapter are exceedingly interested in the matter of fatigue failures of metals.

It is reported that Professor Moore's paper brought out one of the most interesting discussions that has ever been held before the Chicago chapter.

A special meeting of the Chicago chapter was held at the Hamilton Club on Friday evening, March 23rd, at which time Dr. Rosenhain, of the National Physical Laboratory of Teddington, England, presented a paper entitled "The Constitution of Metals and Alloys."

Dr. Rosenhain, who is an authority on the subject of metallic alloys, has been traveling and lecturing throughout the eastern and central states of the United States for the past four or five weeks and has delivered many exceedingly interesting lectures. Dr. Rosehain has a very pleasing personality and a very fine address, and the Chicago members turned out in full force to welcome their distinguished guest.

CINCINNATI CHAPTER

The Cincinnati chapter of the American Society for Steel Treating held its regular monthly meeting on March 8th, at 8:00 p.m. at the Ohio Mechanics Institute, Canal and Walnut Streets.

The program for the evening was a paper by E. W. Ehn, metallurgist with the Timken Roller Bearing Company, Canton, Ohio, who presented a paper entitled "The Relation Between Quality of Steel and Case Hardening Results."

Mr. Ehn is an authority on case hardening and carburizing and brought out many interesting facts in reference to this process.

The meeting was very well attended and proved to be a decided success.

CLEVELAND CHAPTER

On March 12th the Cleveland chapter of the American Society for Steel Treating held a joint meeting with the Ohio Section of the American Institute of Mining and Metallurgical engineers in the Ball Room of the Hotel Winton, at which time Dr. Walter Rosenhain, chief of the metallurgical department of the National Physical Testing Laboratory of Teddington, England, presented a very capable paper entitled—"The Structure and Constitution of Metallic Alloys."

Dr. Rosenhain outlined in considerable detail the methods that are employed in obtaining data for the plotting of equilibrium diagrams for various alloys. He showed many stereopticon illustrations of apparatus which he is using in his laboratory in England and which has assisted him to a large extent in arriving at the many valuable conclusions upon which he has built his numerous theories.

This meeting was attended by about 250 members and guests of the two societies and following the paper numerous questions pertaining to the subject of the paper were asked of Dr. Rosenhain.

This meeting was one of the best the Cleveland chapter has had during the present year and was preceded by a dinner served in honor of our distinguished guest.

At four o'clock on Monday, March 12th, preceding the joint meeting, Dr. Rosenhain presented a paper before the faculty of Case School of Applied Science and members and guests of the Ohio Section of the Mining and Metallurgical Engineers and the Cleveland chapter of the American Society for Steel Treating at the Case School of Applied Science, entitled "Hardness and Hardening," at which time he brought out several of his theories on the hardening of metals and metallic alloys.

On Tuesday afternoon at four o'clock, Dr. Rosenhain again presented a paper before the faculty of Case School of Applied Science and members and guests of the Ohio Section of Metallurgical Mining Engineers and the Cleveland chapter of the American Society for Steel Treating, on the subject of "Strain and Fracture in Metals," in which he developed numerous theories as to the mechanics of a progressive failure of any steel or other alloy in actual service.

All of those who had the privilege of hearing Dr. Rosenhain present

these three lectures were highly edified and certainly profited by these very capable talks.

The next regular meeting of the Cleveland chapter will be held on March 23rd, at which time the members of the National Nominating Committee of the Society will give short talks on metallurgical subjects.

In anticipation of the fact that many members of the American Society for Steel Treating will be attending the 27th annual convention of the American Foundrymen's association, the Cleveland chapter of the American Society for Steel Treating extends a cordial invitation to our visiting members and guests to attend our regular April monthly meeting held on April 27.

The meeting will be held in the rooms of the Cleveland Engineering Society, at 8 p. m. The speaker for this meeting will be Dr. P. D. Merica, metallurgist for the International Nickel Company, who will present a paper entitled "Nickel and Nickel Alloys."

DETROIT CHAPTER

The Detroit chapter of the American Society for Steel Treating held its postponed meeting on "Sheet Steel" on March 5th, 1923, at 8:00 p.m. in the east wing of the 15th floor of the General Motors building on West Grand Boulevard and Woodward Avenue.

The speaker for the meeting was H. M. Williams, research metallurgist for the General Motors Laboratories, of Dayton, Ohio, who addressed the chapter on the subject of "Automobile Sheet Steels," and illustrated his talk with a moving picture film showing the manufacture of sheets as practiced by the American Rolling Mills Co. of Middletown, Ohio.

Mr. Williams' paper brought forth a great deal of comment and discussion inasmuch as nearly all of the metallurgists and members of the Detroit chapter of the Society are interested in the use of sheets at least for automotive purposes. This subject has created considerable interest in the past and Mr. Williams' paper brought out many valuable points of information pertaining thereto.

The usual get-to-gether dinner was served at 6:00 p.m. in the cafeteria of the General Motors Company and was attended by a goodly number of members and guests.

The Detroit chapter may or may not win the contest for attendance and increase of membership but to those who attended last Monday's meeting this did not matter. As long as the chapter can draw an attendance of over 300, even with a prominent speaker, it will hold its first place among the chapters. Every automobile plant was represented. There were those who did not attend meetings for months, there were those who do not belong to the society because they think they know too much to gain anything by it; and there were those who do not belong to it because they are afraid to be in contact with fellow metallurgists, afraid of losing the mysterious prestige their own mind built around themselves. They see a fading halo around their head in the twilight, but this disappears at daylight. Well, halo or no halo, they were all there.

The Detroit chapter is a member of the Detroit Technical Societies

which is made up of a number of engineering and chemical societies. There is one joint meeting every month under the auspices of one of the member societies. The turn out is usually very fair. To our Monday's meeting the members of the affiliated societies were also invited and the attendance was the highest we have reached this year, as about 350 attended the meeting.

Of course, we had quite a drawing card. Dr. Walter Rosenhain, of London, England, one of the best known metallurgists, gave a lecture on "Strain and Fracture in Metals." It was a happily chosen subject for the mixed metallurgist, steel treater and engineering audience. It was an interesting subject to the engineers, popular with the steel treaters and a pleasant review for the metallurgists.

Dr. Rosehain's paper was very well illustrated with stereopticon slides and he brought out many valuable points in connection with the progressive failure of metals in service.

As will be recalled, Dr. Rosenhain is the author of many contributions to the science of metallurgy, both ferrous and nonferrous, and has recently delivered the honorary lecture entitled "The Nature of Solid Solutions," before the Mining and Metallurgical Engineers at their February convention in New York City.

Dr. Rosenhain is not only a very capable metallurgist, but in addition is very entertaining and pleasing in his address.

Dr. Rosenhain delivered three lectures at the University of Michigan, at Ann Arbor, and all these lectures were very well attended by the members of the Detroit chapter. (It's only too bad that our secretary didn't fill our attendance cards to our members there, it would have come very handy in our race for record attendance).

After our chapter's meeting many of us looked at members of the technical societies with eyes that twinkled and said, "See, that's us."

Detroit fellows, now let us tap each other's back. Just a little.

MILWAUKEE CHAPTER

The Milwaukee Chapter of the American Society for Steel Treating held a meeting on Friday evening, March 16th, at 8:00 p. m. in the Blatz Hotel, E. Water and Oneida Streets.

The speaker for this meeting was Dr. Enrique Touceda, consulting metallurgical engineer associated with the American Malleable Castings association, who presented a very interesting and capable paper entitled "The Manufacture of Malleable Iron."

Dr. Touceda is a very well-kown metallurgist and has done an enormous amount of very fine work with reference to malleable cast iron. It is through his efforts that the present day standards of malleable cast iron are as high as they are and that the uniformity of malleable cast iron throughout the country is as constant. This is due to the very close check-up which is continually made on the product of the various manufacturers belonging to the association.

Following Dr. Touceda's paper a very interesting discussion ensued.

Prior to the meeting a get-to-gether dinner was served in honor of Dr. Touceda, at which time a goodly number of members and guests were present.

NEW HAVEN CHAPTER

The New Haven chapter of the American Society for Steel Treating held a meeting on Friday evening, March 16th, at eight o'clock, in the assembly room of the New Haven Gas Light Company, 70 Crown Street, New Haven, Conn.

The speaker for the evening was Stanley P. Rockwell, metallurgical engineer of Hartford, Conn., who spoke on the subject of "Hardness."

Mr. Rockwell, who is the inventor of the Rockwell Hardness Tester, gave a practical demonstration in the use of his machine in obtaining the hardness of specimens. In this practical demonstration Mr. Rockwell showed the flexibility and adaptability of his machine in testing the hardness of various sizes and shapes of material both in soft and hardened conditions.

Prior to this meeting an informal get-to-gether dinner was served at the Cafe Mellone at six o'clock, at which time a good-sized turnout was had.

NEW YORK CHAPTER

The New York chapter of the American Society for Steel Treating held its regular March meeting on Wednesday, March 21, at 8:15 p. m., in the assembly room of the Merchants association of New York, ninth floor the Woolworth building.

The chapter had been especially fortunate in being able to obtain W. R. Shimer, metallurgical engineer of the Bethlehem Steel Co., Bethlehem, Pa., to present a paper entitled, "The Manufacture of Steel."

Mr. Shimer has had many years of experience in the steel business and has a vast fund of information on the subject. He delivered a very interesting and capable paper, which covered a discussion of special steels, dealing with their fatigue resisting values. Mr. Shimer illustrated his paper with stereopticon slides.

The usual get-together dinner was served at 6:00 p. m., at the Post Keller restaurant in the Woolworth building and was attended by a good sized number of guests and members of the chapter.

NORTH WEST CHAPTER

The Northwest chapter of the American Society for Steel Treating held a joint meeting with the Twin City Foundrymen's Association on March 17th, at 7:45 p.m. at the Manufacturers' Club, 200 Builders Exchange, Minneapolis, Minn.

The speaker for the meeting was Dr. Enrique Touceda, who is consulting engineer for the American Malleable Castings Association. Dr. Touceda presented a paper entitled "Malleable Iron Castings—Their Production, Properties and Uses," and brought out many valuable points of information on this subject.

Dr. Touceda is a recognized authority on the subject of malleable castings and to his efforts are largely due the present day improvements

in the quality of malleable cast iron through his diligent work with the American Malleable Castings Association.

The meeting was one of the most important that the chapter has held this year and was of particular interest to steel treaters as well as foundrymen inasmuch as the proper annealing of white iron castings is a very important operation in the production of malleable castings.

In honor of Dr. Touceda a dinner was served at 6:30 p.m. which was well attended by members of both societies.

PHILADELPHIA CHAPTER

The Philadelphia chapter of the American Society for Steel Treating held its regular monthly meeting on Friday evening, March 23, at 8:00 p. m., in the Engineers' Club rooms, 1317 Spruce street, Philadelphia.

The program for this meeting was a paper by Dr. P. D. Merica, director of research at the International Nickel Co., who presented a paper entitled, "Metallurgy and Heat Treatment of Nickel and Its Alloys."

In this talk Dr. Merica traced the history and development of the metallurgy of nickel and described in detail the several principal methods used for the refining of nickel.

As nickel has many uses in the industry, the principal one of which is its use in the production of nickel steel, there being over 50 per cent of the total nickel production of the world going into the manufacture of nickel steel, it was pointed out that the two principal uses of nickel steel are for armour plate and automotive parts.

In his paper Dr. Merica gave a series of curves and data indicating the value and the usage of nickel in steel. It was also shown that merit index of nickel steel was considerably higher than that of the carbon steel of equal carbon content and compared favorably with other alloy steels.

Of the many other uses of nickel the following may be named as principal:

Its use combined with a percentage of copper in coinage.

Its extensive use in the alloy known as "German silver," which is a nickel-copper-zinc alloy and cupro-nickel.

It was stated that about 5 per cent of the total nickel production is used for nickel-plating work.

Following Dr. Merica's paper, A. H. Kingsbury, metallurgical engineer, Atha Works of the Crucible Steel Co., gave a practical talk entitled, "Tool Room Troubles." As Mr. Kingsbury has had charge of the high-speed steel production for the Crucible Steel Co. for many years he has had many years of practical experience in heat treating and developed a very interesting talk as evidenced by the large amount of discussion which followed his paper.

The usual get-together dinner was served at 6:30 p. m., in the club dining room and it was attended by a large number of members and guests.

The meeting itself was attended by a large number of members and guests and proved to be one of the most interesting meetings that the Philadelphia chapter has had this year.

PITTSBURGH CHAPTER

Professor F. F. McIntosh, associate professor of metallurgy, Carnegie Institute of Technology, gave a very interesting talk on "The Application of

Fatigue Testing of Metals to Industrial Problems," before the Pittsburgh chapter of the American Society for Steel Treating at their regular monthly meeting on March 8, 1923, at the William Penn hotel.

Professor McIntosh presented some very valuable and interesting information regarding fatigue-resisting values of upset seamless drill tube of low and high-carbon composition, and their comparison in the raw worked and the annealed structural condition. His research work established the fact that the life of a 0.50 per cent carbon tube material, after upsetting for enlargement of section for threading, is very short and invariably fails at the zone which becomes granular and strained because of the partial heating of the ends of the tube.

The use of low-carbon steel, which has been thought necessary to avoid dangerous embrittling, was found to offer very little insurance against these failures. A short-time anneal, however, gave an endurance limit of satisfactory value and equal to that of the original material. An increase in carbon content from 0.15 per cent to 0.50 per cent, in conjunction with an anneal after upsetting, gave test values which were very much in excess of any results ever before obtained. These results were substantiated by service records presented. A very animated discussion ensued in which practically the entire assembly participated.

The meeting was probably the most interesting one of the season and was well attended.

ROCKFORD CHAPTER

The Rockford chapter of the American Society for Steel Treating held its regular monthly meeting on Friday, March 16, at 7:00 p. m., at the Nelson hotel, at which time the usual get-together dinner was served to a goodly number of members.

The program for this meeting consisted of reports by the members who attended the winter sectional meeting in Chicago and were followed by round table talks on various metallurgical subjects.

This meeting was well attended and many valuable thoughts and ideas were brought out which proved to be of value and benefit to the members.

SCHENECTADY CHAPTER

The regular February meeting of the Schenectady chapter was held on February 26th at the American Locomotive Works, Schenectady.

The speaker for the evening was L. S. Fuller, of the General Electric Research Laboratory, who addressed the chapter on the subject of "Hydrogen: The Dr. Jekyl and Mr. Hyde of Metallurgy," pointing out the dangers resulting from the action of pickling and plating baths on steel, and especially on hardened steel, due to the liberation of nascent hydrogen. Mr. Fuller also brought out points on the many useful applications of hydrogen with no attendant dangers.

This meeting was very well attended and the speaker's paper brought forth much valuable and interesting discussion.

SPRINGFIELD CHAPTER

The Springfield chapter of the American Society for Steel Treating held a meeting on Thursday evening, March 1st, at the Technical High School hall, Elliot Street.

The program for the evening was a paper by J. V. Emmons, metallurgist of the Cleveland Twist Drill Company, and treasurer of the National Society, who presented an interesting paper on the "Machinability of Tool Steel."

Mr. Emmons' paper was very capably presented and brought forth a large amount of interesting and valuable discussion.

In addition to Mr. Emmons' paper a series of moving pictures were exhibited entitled "The Uses and Abuses of Twist Drills." This film is the property of the Cleveland Twist Drill Company and outlines a six weeks' course in Drilling. The film shows how to grind a drill to eliminate as far as possible breakage during drilling and shows how production can be increased by sharpening a drill in the proper manner. It also shows many instances of high speed drilling and some of the examples shown were record time for the drilling of the slab in question.

This meeting was very well attended and proved to be a decided success.

SOUTH BEND CHAPTER

The South Bend chapter of the American Society for Steel Treating held its March monthly meeting on the 14th at the No. 2 Plant of the Studebaker Corporation.

In accordance with the policy of having a member of the chapter read a paper at each meeting of the chapter, Leo Jordan, read a paper entitled: "Temperature Measurements by Pyrometers and Maintenance of Instruments Used."

Mr. Jordan illustrated his paper by the use of lantern slides and brought out some exceedingly interesting information with reference to the subject of pyrometry. This paper brought forth some interesting and valuable discussion.

The main speaker of the evening was E. J. Janitzky, metallurgical engineer of the Illinois Steel Company, South Chicago, Illinois.

The subject of Mr. Janitzky's paper was "Melting Processes Employed In The Manufacture Of Steel." This paper was indeed very instructive and described in detail steel mill practices including the open-hearth, Bessemer, and electric furnace methods of producing steel.

Following Mr. Janitzky's talk two reels of moving pictures taken at the plant of the Illinois Steel Company, South Works, were exhibited, and Mr. Janitzky answered questions with reference to them after they had been exhibited. The meeting was very well attended, there being 78 members and guests present.

At the April meeting of the chapter, Professor H. M. Boylston, of Case School of Applied Science will be the speaker, and a joint meeting will be held with the American Chemical Society.

SYRACUSE CHAPTER

The Syracuse chapter of the American Society for Steel Treating held its regular monthly meeting on March 15, at the Yates hotel, at which time S. C. Spalding, of the Halcomb Steel Co., Syracuse, presented an interesting paper entitled, "Carburizing."

Mr. Spalding has done a great deal of very valuable work along carburizing lines and has presented several very interesting papers, notable among which is his paper which appeared in the August, 1922, issue of TRANSACTIONS.

Following Mr. Spalding's presentation, a large amount of interesting and valuable discussion was brought out.

The usual get-together dinner was served at 6:00 p. m., and was attended by a goodly number of members and guests.

An attendance of about 50 members and guests was the score for the meeting proper. The meeting proved to be highly successful and without doubt many of the members and guests obtained much valuable information from Mr. Spalding's very capable presentation.

TRI-CITY CHAPTER

The Tri-City chapter of the American Society for Steel Treating held its regular monthly meeting March 15, at the Davenport Chamber of Commerce.

This meeting was a joint meeting of the Tri-City chapter and the Quad-City Foundrymen's association. The meeting was called to order at 8 p. m. by the chairman, who announced the results of the "Membership and Attendance Contest" as of Feb. 28, showing that the Tri-City chapter was in second place and had secured the largest increase in membership.

A nominating committee for the officers for the ensuing year was appointed by the chairman. The committee is composed as follows:

Harold Brown, chairman,
A. H. Putnam,
C. H. Lage.

The meeting was then turned over to the Quad-City Foundrymen's association and they held a short business session. Then the meeting was turned back to the chairman of the Tri-City chapter and he introduced the speaker of the evening, Dr. Enrique Touceda, of Albany, N. Y., consulting engineer of the American Malleable Castings association. Dr. Touceda spoke on the subject of "Malleable Cast Iron." Dr. Touceda traced the historical development of iron making, and showed how the blast furnace was first evolved. He discussed the methods of grading pig iron and showed that the grading by fracture did not give the correct results.

In order to secure a white iron which will give malleable castings with the desired physical properties, it is necessary to have the white iron of a fairly definite chemical composition. Otherwise, considerable difficulty may be experienced in the annealing of these castings. Consequently, it is essential to have very close chemical control in the successful operation of a malleable iron foundry. Dr. Touceda showed pictures of melting furnaces and annealing furnaces and told why the

air furnace was generally used for the production of the white iron. His talk was illustrated with a large number of lantern slides. A considerable number of photographs of the structures of various irons were shown and discussed. The results of improper composition and of improper annealing practice were clearly shown by these photographs.

Dr. Touceda stated that approximately 1,200,000 tons of malleable castings were produced annually and that the major portion of this production was used in the automotive industry. A rising vote of thanks was tendered to Dr. Touceda for his kindness in coming to the Tri-Cities and addressing the joint meeting. The meeting adjourned at 10:30 p. m. Attendance at the get-together dinner, 103. Attendance at the meeting, 115.

WASHINGTON CHAPTER

The February meeting of the Washington chapter was held Tuesday evening, February 27th, at 8:00 p.m. in the auditorium of the new Interior Department building, corner of Eighteenth & "F" Streets, Northwest.

The program for this meeting was a paper by J. V. Emmons, metallurgist of the Cleveland Twist Drill Company, and treasurer of the National Society, entitled "Machinability of Tool Steel."

Mr. Emmons discussed various phases of his work in studying the relationship between machinability of steels for use in the manufacture of tools and the methods of obtaining the desired results by the proper control of annealing and heat treating processes.

The presentation of Mr. Emmons' paper required about forty-five minutes and was followed by a one hour and thirty minute discussion which brought forth many valuable and interesting features.

In addition to Mr. Emmons' paper, J. J. Crowe, metallurgist with the Philadelphia Navy Yard, and a director of the national society, gave a short talk on a metallurgical subject.

Mr. Laury, metallurgist with the Bethlehem Steel Company, Bethlehem, Pa., presented a short talk on some of the plans for the sectional meeting which will be held in Bethlehem in June of this year.

The February meeting of the Washington chapter was unusually successful and will undoubtedly raise the chapter's standing in the attendance and membership list.

On Friday evening, March 16, 1923, the Washington chapter of the American Society for Steel Treating held a meeting in the auditorium of the new interior department building, at the corner of Eighteenth and F streets, at which time, Jerome Strauss, chief chemist, United States naval gun factory, Washington, D. C., presented a very capable paper entitled, "Performance of High-Speed Cutting Tools."

Mr. Strauss pointed out that modern mechanicalized production has reached its present stage of development through the co-ordination of many factors, prominent among which is the application of high-speed steel tools. It was indicated that information and data pertaining to the variations in properties and performance of high-speed tools as effected by composition,

manufacturing methods, heat treatment and operating conditions are not as well known as they should be, although a great deal of research has been done along those lines.

Mr. Strauss brought out many of these factors. Following his paper a very interesting discussion was held.

WORCESTER CHAPTER

The regular monthly meeting of the Worcester Chapter of the American Society for Steel Treating was held Tuesday evening, March 22nd, at 8:15 p. m., at the Worcester Polytechnic Institute, in the Electrical lecture-room, Salisbury Street, Worcester, Mass.

The program for this meeting was a feature motion picture entitled "The Story of Steel," which has recently been produced by the U. S. Bureau of Mines.

This picture proved to be exceedingly interesting, tracing the manufacture of steel from the ore beds to the finished product. The story of the film was very interestingly told by a competent lecturer.

The meeting was exceptionally well attended and proved to be interesting to all.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A repesents Associate Member; S represents Sustaining Member; J represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

NEW MEMBERS

ALLEN, H. B., (M-12), c/o Henry Disston & Sons Co., Inc., Philadelphia, Pa.
AMMONS, CLEMENT, (M-2), 410 Seeberger Street, South Bend, Ind.
ANDERSON, JOHN W., (M-3), c/o Maxwell Motor Corp., New Castle, Ind.
ANDERSON, THEODORE G., (M-2), 2831 No. Maplewood Avenue, Chicago, Ill.
ATWATER, R. M., (A-2), 1108 Majestic Bldg., Detroit, Mich.
BEAM, DANIEL A., (M-3), c/o The John Illingworth Steel Co., Frankford, Philadelphia, Pa.
BETTENDORF CO., (S-3), Bettendorf, Iowa.
BRICKNER, H. A., (Jr.-2), c/o American Chain Co., Inc., York, Pa.
DeMOSS, IRA M., (M-3), Haney Avenue, South Bend, Ind.
DONAHUE, D. A., (M-3), 1706 E. Ewing Avenue, South Bend, Ind.
DORSEY, C. B. Jr., (M-1), 523 South Main Street, Geneva, N. Y.
DOWNS, BERNARD I., (Jr.-3), Stafford Avenue, Forestville, Conn.
CLARK, HOMER A., (M-2), 1674 Pingree Avenue, Detroit, Mich.
COLEMAN, WM. B., (M-3), 588 Drexel Bldg., Philadelphia, Pa.
COLONIAL STEEL CO., (S-3), c/o Mr. James Dunlevy, 145 Water Street, New Haven, Conn.
CREUSERE, GORDON C., (A-3), 49 North Avenue, Highland Park, Mich.
CRANS, W. B., (M-1), 1503 St. Clair Avenue, Detroit, Mich.
CROSEY, W. H., (M-2), c/o Pollak Steel Co., Cincinnati, O.
CROSS, HOWARD C., (Jr.-2), 1222 Eighth Street, Washington, D. C.
ESCH, EDWARD, (M-2), 628 North Scott Street, South Bend, Ind.
FINANCE OFFICE, CHEMICAL WARFARE SERVICE, (Sub.-1), Edgewood Arsenal, Edgewood, Md.
FISHER, EDWIN J. P., (M-3), 48 South Main Street, Wallingford, Conn.
FOSNIGHT, P. F., (A-2), 222 W. Larned Street, Detroit, Mich.
FRASER, WILLIS P., (M-2), c/o New Departure Mfg. Co., Bristol, Conn.
FRENCH & HECHT, (S-3), Davenport, Iowa.
GEOMETRIC TOOL CO., THE (S-3), New Haven, Conn.
GIFFORD, HARRY L., (M-2), Box 215, Midland, Pa.
GREEMAN, O. W., (M-12), 24 Hendricks Place, Indianapolis, Ind.
GREEN, HARRY J., (M-3), 1940 West Vermont Street, Indianapolis, Ind.
GRIFFITHS, JOHN W., (M-3), Bethlehem Steel Co., Bethlehem, Pa.
GRIGGS, E. R., (M-10), Lufkin Rule Co., Saginaw, Mich.
GRILL, C. H., (M-2), 5479 Harper Avenue, Chicago, Ill.
HAHNEFELD, CHAS., (M-3), Studebaker Corp., South Bend, Ind.
HARTFORD ELECTRIC LIGHT CO., (S-2), Hartford, Conn.
HAYES, FULLWOOD P., (Jr.-3), 218 West Ruscomb Street, Philadelphia, Pa.
HIBERT, CHAS., (M-3), 723 Washington Street, Oakmont, Pa.
HOPP, WILLARD C., (M-2), Studebaker Corp., South Bend, Ind.
HULL, W. H., (M-3), 622 Eighteenth Street, Moline, Ill.
JOHNSON, CHAS., (M-2), 2011 South Clyde Street, South Bend, Ind.
JOHNSON, JOHN, (M-1), c/o Miehle Printing Press & Mfg. Co., Chicago, Ill.
JOHNSON, VICTOR, (M-1), 319 Herkimer Street, Syracuse, N. Y.
JOHNSTON, JAMES G., (M-3), c/o Dort Motor Car Co., Flint, Mich.
JORDAN, RICHARD C., (A-3), 2923 Wasp Road, Fairview, Camden, N. J.
KAVANAUGH, M. R., (M-3), Studebaker Corp., South Bend, Ind.
KROPF, FRED (M-2), 159 Kinsey Avenue, Mt. Auburn, Cincinnati, O.
LINCOLN, H. W., (M-3), c/o Conn. Light & Power Co., Waterbury, Conn.
LOOP, J. F., (M-3), Y. M. C. A., Moline, Ill.
LORENZ, HERBERT, (M-2), 364 Eastlawn Avenue, Detroit, Mich.
LUCKETT, D. J., (M-3), 712 East Fourteenth Street, Davenport, Iowa.
MILLARD, JAS. M., (A-3), P. O. Box 693, Providence, R. I.
MOELLER, ERNEST E., (M-4), 3218 McKinley Boulevard, Milwaukee, Wis.
MONTGOMERY, HARLEY A., (S-2), c/o Wayne Soap Co., Copeland & M. C. R. R., Detroit, Mich.

MORRIS, WHEELER & CO., (S-3), Thirtieth & Locust Streets, Philadelphia, Pa.
NEMETZ, JULIUS, (M-2), 915 Second Avenue, Rockford, Ill.
NEUNER, C. L., (M-2), c/o Interstate Iron & Steel Co., E. Chicago, Ind.
OATMAN, RALPH B., (M-3), 6908 Harper Avenue, Chicago, Ill.
PARRISH, J. G., (M-3), The Linograph Co., Davenport, Iowa.
PAQUE, E. J., (M-2), 980 Fairbanks Avenue, Cincinnati, Ohio.
PESKOWITZ, S., (M-1), 840 Sumner Avenue, Syracuse, N. Y.
PETERSON, N. P., (M-3), 278 DeCorcelle Street, Montreal, Quebec, Canada.
PURINTON, FOREST G., (M-2), c/o Patent Button Co., P. O. Box 1028, Waterbury, Conn.
RITZLOFF, OTTO, (M-1), Worthington Pump & Machine Corp., Cudahy, Wis.
STRAND, C. H., (M-3), 2955 East Ninety-second Street, Cleveland, O.
TROXWELL, G. B., (M-3), 185 Charles Street, Easton, Pa.
VANNIER, EDGAR, (M-3), The Linograph Co., Davenport, Iowa.
VOSS, H. W., (M-2), 1765 Olive Avenue, Chicago, Ill.
WAARICH, OTTO C., (M-3), c/o Pheoll Mfg. Co., 5700 Roosevelt Road, Chicago, Ill.
WAECHTER, J. EDMUND, (M-3), c/o Brown-Sharpe Mfg. Co., Providence, R. I.
WAKELAM, JAMES P., (M-3), Y. M. C. A., Moline, Ill.
WEAVER, WM. G., (M-10), Department of Mechanical Engineering, University of Cape Town, Cape Town, South Africa.
WELKER, E. H., (A-1), 222 West Larned Street, Detroit, Mich.
WENZINGER, CARL J., (Jr.-2), Swarthmore College, Swarthmore, Pa.
WIDEMAR, C. H., (Jr.-3), 7312 Frankford Avenue, Holmesburg, Pa.
WINDFELDER, CLIFTON, (A-3), 858 Forty-seventh Street, Milwaukee, Wis.
YALE & TOWNE MFG. CO., (Sub.-1), Works Library, Stanford, Conn.

CHANGES OF ADDRESS

ABEGG, W. A., from 653 North Main Street, to 2533 East Twenty-sixth Street, Los Angeles, Cal.
ATKINS, G. F., from 109 East St. Clair Street, to E. C. Atkins & Co., Indianapolis, Ind.
BUTT, HOWARD, from 1156 Leader-News Bldg., Cleveland, to 9 Neponset Street, Worcester, Mass.
CHAMBERLAIN, G. D., from Box 431, to American Chain Co., Bridgeport, Conn.
COWELL, W. T., from 4239 Hamilton Avenue, to 1851 Chase Avenue, Cincinnati, O.
DAVIS, F. G., from 2444 West Grand Boulevard, Detroit, to Iroquois Steel Co., Buffalo, N. Y.
DIEDERICHS, WM. J., from 1027 Lincoln Way, to 915 Duff Avenue, Ames, Iowa.
DREW, E. G., from Y. M. C. A., Moline, Ill., to 273 West Third Street, Mansfield, O.
DREXLER, CHAS., from Stevenson Gear Co., to 311 East South Street, Indianapolis, Ind.
FROST, M. A., from 1005 Alexander Street, to 700 Chestnut Street, Latrobe, Pa.
HARRIS, F. E., from 205 West Anne Street, to 230 Grace Street, Flint, Mich.
HARRIS, H. H., from 122 South Michigan Avenue, Chicago, to 405 West First Street, Boston, Mass.
HEATH, LESLIE J., from Simonds Mfg. Co., Fitchburg, to 33 Logan Avenue, Medford, Mass.
JAYME, W. A., from 19 Pomander Walk, West Ninety-fifth Street, New York City, to 1120 Piedmont Avenue, Canton, O.
KIRKPATRICK, T. L., from Wheelock, Lovejoy Co., Cambridge, Mass., to A. E. Hunt Steel Co., Boston, Mass.
KLOPSCH, O. Z., from 3250 Highland Place, to 1813 Columbia Road, Washington, D. C.
KUTAR, P., from 4617 Center Avenue, to 258 Oakland Avenue, Pittsburgh, Pa.
LAGE, C. H., from Linograph Co., Davenport, Iowa, to Yellow Sleeve Valve Engine Co., East Moline, Ill.
LOVE, W. D., from 1437 Franklin Street, Detroit, to Latrobe Steel Co., New York City.
NEWCOMB, E. S., from 14017 Baldwin, to 1740 East Twelfth Street, Cleveland, O.
NIXON, H. K., from 326 Hendrie Street, Detroit, to 424 Pleasant Street, Royal Oak, Mich.
PENNEY, R. L., from 34 West Rock Avenue, New Haven, to 21 Lincoln Street, New Haven, Conn.
REINHOLD, B., from 653 North Main Avenue, to 2533 East Twenty-sixth Street, Los Angeles, Cal.

SADTLER, C. B., from 1615 North Meade Avenue, to Western Electric Co., Chicago, Ill.
SHERMAN, P. B. Jr., from Y. M. C. A., Canton, O., to 147 Exeter Terrace, Buffalo, N. Y.
STEPAN, A. C., from 589 East Illinois Street, to 230 East Ohio Street, Chicago, Ill.
SYKES, LEWIS, from 1412 Baird Avenue, to New York Shipbuilding Corp., Camden, N. J.
WATSON, J. M., from Hupp Motor Car Corp., to 226 Eason Avenue, Highland Park, Mich.
WILLETS, C. L., from 117 Dearborn Place, to 1040 West Colvin Street, Syracuse, N. Y.
WILLS, WM. H., from 437 South Avenue, Wilkinsburg, Pa., to 307 Roosevelt Avenue, Dunkirk, N. Y.
ZETZER, HENRY, from 2872 East 112th Street, to 3630 Shaker Road, Cleveland, O.

MAIL RETURNED

C. F. BOYD, Nordyke & Marmon Co., Indianapolis, Ind.
T. B. FUNK, Midwest Engineering Co., Indianapolis, Ind.
C. P. MORRELL, 511 Bulkley Bldg., Cleveland, O.
C. F. TEUBER, Peoples Gas Light & Coke Co., 325 South Michigan Avenue, Chicago, Ill.

Abstracts of Technical Articles

(*Continued from Page* 776)

SOFTENING GRAY IRON BY ANNEALING. By Dr. I. E. Piwowarsky, in *Forging and Heat Treating,* February, 1923, page 127.

This article is a translation from Stahl und Eisen and deals with the object and theory of the annealing of cast iron.

ADVANTAGES OF BUILT-UP DIE CONSTRUCTION. By C. E. Stevens, chief engineer, White Sewing Machine Co., Cleveland, Ohio, in *Machinery,* for March, 1923, page 528.

The author states that built-up dies are those in which the surfaces that are subjected to wear and that are difficult to machine are made in two or more parts and properly assembled. He also describes the advantages of this construction.

THE HEAT TREATMENT OF ALLOY STEELS. By R. R. Moore and E. V. Schaal, in *Forging and Heat Treating,* February, 1923, page 113.

The authors discuss the effect of heat treatment upon the metallographic and physical characteristics of chrome-nickel, chrome-vanadium, and chrome-molybdenum steels.

HEAT TREATMENT OF ELECTRIC CARBON AND ALLOY FORGING STEELS. By L. J. Barton, in *Forging and Heat Treating,* February, 1923, page 102.

The effect of heat treatment on the physical properties of plain carbon and alloy steels containing nickel, chromium, molybdenum and vanadium are discussed.

TRANSACTIONS

of the

American Society for Steel Treating

Vol. III Cleveland, May, 1923 No. 8

SECRETS

IT IS within the memory of most of us when the art of steel treating was regarded as a very secret and mysterious process, and it is to be noted that there are at the present time a few firms who still believe they have secret processes and methods by means of which they produce a superior product to that of others in a similar line.

These firms work on the principle that they should keep their heat treating department under lock and key and in fact build the place so secure and air-tight that it would not be possible to gather information even with the aid of a periscope and the proverbial knot-hole.

They work on the principle that what they have they will keep, and they rest secure on the supposition that what they have no one else will be able to secure. In other words, they have constructed around their heat treating department a windowless stone wall or they have pulled down the blinds so that no light from outside may be able to penerate the innermost recesses of their secret archives.

As stated before, there are few firms at the present time using this ancient attitude. The majority of them realize that their secret processes and methods are all "bunk" and that the development in metallurgical lines has been so pronounced that the average investigation will portray practically all of the secrets they think rest secure with them.

The remarkable change of attitude that has come over the various manufacturing industries with reference to granting the privilege of visitation or exchange of ideas is indeed quite pronounced and is a further evidence of the recognition of the application of scientific principles to the class of work in which they are engaged. Probably the largest factor contributing to the raising of the blinds or tearing down of the stone wall around the various heat treating rooms is the general trend of all organizations having for their principle the idea of service to their fellowmen. In direct contrast to their former habits, there are very few worthwhile establishments in the country today that do not have the open-door policy and are willing to have visitors go through their heat-treating departments and if they so desire, ask any questions they may and secure as much information as is their wish.

It is impossible that any single individual or firm knows all that is to be acquired with reference to the art of treating steel, and there are very few, who, meeting on common grounds and exchanging ideas with reference to methods and equipment, but may be of mutual benefit.

As an illustration of this point, we often recall the statement of the value of exchange of ideas. If you have a dollar and we have a dollar and

we exchange dollars then each of us still has a dollar. However, if you have an idea and we have an idea and we exchange ideas, then each of us has two ideas, which of course makes us better equipped to carry on our work and at the same time gives each individual a feeling of the application of the principle of reciprocity, which, after all, is an admirable solution to our many intricacies and vagaries of life.

When all things are summed up in the final reckoning there is no question but that the majority of individuals will be judged by the use they have made of the talents and opportunities given them, and inasmuch as we pass this way but once is it not a better plan to do all the good and service that it is possible for us to do so that it may be said of us that "we gave to the world the best we had," and in giving to the world the best we had there is no doubt but that "the best in the world will come back to us."

SHOOTING

WE ARE reminded of ancient days when among the hills and on the farm we were accustomed to accompany Dad on his squirrel hunting expeditions. Dad held the reputation of being a crack-shot and whenever he would come within the vicinity of one of the squirrel family, Dad would say "See that squirrel?" BANG! "Boy, go get that squirrel." Sure enough, the squirrel would respond to the crack of Dad's rifle and place himself in a convenient position for recovery.

This process would be continued and continued while we followed Dad with trembling hands and shivering knees, waiting for him to give us an opportunity to display the expertness with which we directed a rifle toward the fleeing squirrel.

Along about the seventh squirrel Dad would say "See that squirrel? Boy, take a shot at him!" And then we would with much fear and trembling raise the rifle to our shoulder and shoot at the squirrel. But, the squirrel did not respond as he did when father shot, consequently Dad would look at us with a certain amount of misapprobation for our marksmanship and would say "You do not shoot a high enough percentage," for Dad maintained all along that an individual must shoot 90 per cent or he wasn't shooting at all.

We could not shoot 90 per cent, and we wonder how many people in life "shoot 90 per cent," and that brings us to the point—Is 90 per cent the proper percentage to be attained in shooting at our object? Many of us will not make a record equivalent to that and no one, we believe, is able to shoot 100 per cent for a continuous time because it is human nature to err. Nevertheless, it seems the best thing possible for the majority of us to do is to train ourselves in marksmanship so that when a proposition comes before us for consideration we can aim at it true and level and with the confidence that every marksman must have if the response to his shot will be as he desires.

There is no doubt but that many individuals are too timid to shoot, but in work such as the members of our society are engaged in it is always necessary that there should be some mark, some object, to be obtained, and the better we train our marksmanship; the better we apply ourselves to the problems before us, the better we undertake to deliver a high percentage of hits, the better we will be qualified to perform and dispose of the functions and obligations that are resting upon us in the discharge of our duties.

SHORTER TESTING TIME NECESSARY

RESISTANCE to fatigue and impact are two properties of materials for which there is vital need for greater information. Both of these are of special moment in the automotive industry. Much work has been done on both, yet the field has scarcely been touched.

Many of the impact results are inconclusive. Some even contradict earlier tests done on supposedly similar material and under supposedly similar conditions. Reliable investigators feel that the limitations of the test itself render it difficult, if not impossible, to get check results closer than fifty per cent. It is doubtful if the present type of generally accepted impact test can even be refined to a degree that will produce as close check results as the tensile test. It is expected, though, that with the adoption of a more standard type of testing machine, a more standard type of test piece and more standard control of test operations that the marked disparity in present day tests results will be greatly reduced.

Engineers have been endeavoring for some time to determine the fatigue properties of various metals under various load conditions. The Wöhler method has been the one generally used. It consists in rotating a standard test piece under a definite load for a given period. At best it is an extremely slow test. In many instances over a month of continuous operation is necessary for the determination of the fatigue properties of a single specimen. Appreciating the multiplicity of compositions and loads and in the case of steels, and even in some cases non-ferrous metal, the large number of possible heat treatments, the laboriousness and slowness, to say nothing of the cost of the present method of testing, is apparent to all. At our present rate of progress a hundred years or more would elapse before we would even approach our present knowledge of the tensile properties of material.

The engineers of this country, therefore, should receive with much enthusiasm a test procedure for the determination of fatigue properties which has recently been developed in England. We are informed that it is as rapid as our tensile test and that the test itself can be performed with the same facility and care.

Essentially the test proper consists in rotating a specimen under a given load. Directed against the end of the specimen to which is attached a mirror, is a beam of light which is in turn projected on a scale. This projected beam undergoes but a slight vertical motion when the test specimen is rotated under its fatigue limit but as soon as the fatigue limit is passed the vertical motion of the beam of light is pronounced. This test was described by Dr. Rosenhain in one of his lectures at the time of his visit to this country in February and March of this year. It is also described in the 1922 edition of *Mechanical Testing* by Batson and Hyde. It warrants a careful consideration by all engineers concerned with fatigue properties in metals.

A. E. W.

Bethlehem Plant, Beth

EASTERN SECTIONAL MEETING OF A. S. S. T. AT BETHLEHEM, JUNE 14 AND 15, PROMISES TO BE AN INTERESTING SESSION

THE Eastern Sectional meeting at Bethlehem in June promises to be very interesting. The Lehigh Valley chapter, the hosts at this meeting, have prepared a full program, which includes entertainment for the ladies that will make their trip to Bethlehem one to be remembered.

The business meeting the first day will be held in the Hotel Bethlehem. This hotel, newly built and opened to the public last fall, has splendid accommodations for a meeting of this character, and compares favorably with the modern hotels of the largest cities.

The trip through the Bethlehem plant of Bethlehem Steel Company scheduled for the morning of Friday, June 15, presents an unusual opportunity for members to see the operations in the manufacture of steel.

The steel works at Bethlehem, Pa., extend for a distance of 3¼ miles along the south bank of the Lehigh river, and comprise the Lehigh plant, the Saucon plant and the Northampton plant of Bethlehem Steel Company. These plants occupy an area of 820 acres for manufacture; 1,680 acres additional are owned by the company for plant purposes in Bethlehem. Five railroads enter the city of Bethlehem and serve the steel works—the Lehigh Valley, the Central Railroad of New Jersey, the Philadelphia and Reading, the Lehigh and New England, and the Philadelphia, Bethlehem and New England. Interlacing the Bethlehem yards are 100 miles of standard gage and 14¼ miles of narrow gage railway tracks. The rolling equipment includes 28 standard gage and 21 narrow gage locomotives, and 565 standard gage and 190 narrow gage cars.

The plants at Bethlehem include seven blast furnaces; thirty-four open hearth furnaces; three Bessemer converters; two electric furnaces; iron, steel and brass foundries; ingot mold foundry; treatment shops; six machine shops, rolling mills to produce special and alloy bars; rail and structural mills; fabricating shops; drop, press and hammer forges; two projectile shops with forge, treatment and machine divisions; an armor plate plant; and coke and coke by-products plant.

Members undoubtedly will be interested in the production of steel by the Bessemer and open-hearth methods, and the equipment at the works includes the following:

Lehigh plant: Open-hearth No. 1, consisting of one 10-ton furnace, two 20-ton furnaces, five 40-ton furnaces and three 50-ton furnaces.

lehem Steel Company

Open-hearth No. 3, consisting of four 50-ton basic furnaces and one 50-ton acid furnace.

Two electric furnaces, including one 10-ton and one 3-ton furnace.

The major portion of the output of the above furnaces is special and alloy steels.

Saucon plant: This is a separate unit for the manufacture of rails and

Hotel Bethlehem

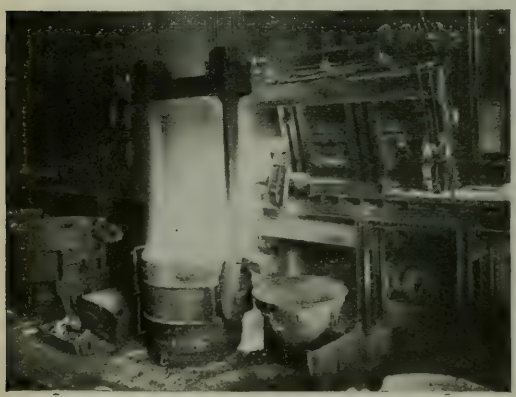
structural steel, it consists of: Open-hearths Nos. 2 and 4, including two 200-ton tilting furnaces and sixteen 75-ton stationary furnaces. The Bessemer department, consisting of three 20-ton converters.

Ore Handling Crane and Storage

inch blooming mill; two 40-inch blooming mills; one 30-inch billet mill; and one 28-inch rail mill.

The division of the Bethlehem works devoted to coke production is known as the Northampton plant. This plant produces coke and coke by-products, and is equipped with four hundred and twenty-four 13½-ton Koppers ovens, consuming an average of 6400 tons of coal daily. The average production of the ovens amounts to 4,500 tons of coke, 45,000,000 feet of gas, 150,000 pounds of ammonium sulphate, 45,000 gallons of tar, and 11,000 gallons of light oil daily.

View of Blast Furnace at Bethlehem



Tapping Steel From 200-Ton Tilting Open-Hearth Furnace

The wide range of equipment of the rolling mills at Bethlehem is seen from the following:

Lehigh mills: Two 22-inch merchant mills; two 12-inch merchant mills; one 10-inch merchant mill; one 9-inch merchant mill; one 8-inch merchant mill; one 35-inch blooming mill; and one 18-inch continuous billet mill; all of which are devoted to special and alloy steels.

Saucon mills: One 48-inch structural (gray) mill; one 42-inch structural (gray) mill; one 28-inch structural mill; one 18-inch structural mill; one 12-inch structural mill; one 46-

The wide diversity of the products of the modern steel plant is not always realized, even by men engaged in auxiliary lines of steel making or working. The products of the Bethlehem plant include:

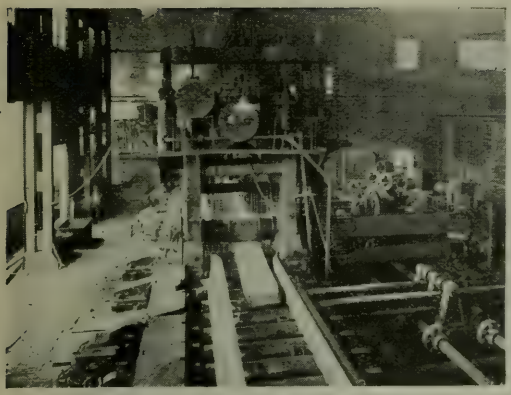
Bethlehem beams, girders and columns; standard beams, channels and angles; fabricated steel for buildings and bridges, etc.

Pig iron, ingots, blooms, billets, bars, slabs and rails.

Tool steel, standard alloy and special steels.

Ingot molds; brass, iron and steel foundry products.

Forgings (drop, hammered, hy-



Rolling an Ingot on a 35-Inch Blooming Mill

draulically pressed); marine and stationary engine cranks (forged hollow or built up).

Forged armor plate; gun carriages; heavy and light ordnance of all calibres; projectiles of all sizes, shrapnel, high explosive shells, fuses; air flasks.

Gas and diesel oil engines; large pumping engines; blowing engines; rolling mill machinery; boilermakers' tools; bridge shop tools; hydraulic machinery; special machinery.

Rolled steel motor truck wheels.

Coke and coke by-products, such as tar, benzol, toluol, retort carbon, motor fuel, ammonium sulphate, crude naphthalene.

The above list indicates what is manufactured at the Bethlehem plant. Other steel making plants of Bethlehem Steel company are located at Steelton, Lebanon, Reading, Johnstown, and Coatesville, Pennsylvania; at Lackawanna, New York; and at Sparrow's Point, Md.

After the trip of inspection through the Bethlehem Steel company plant Friday morning, luncheon will be served to the members in the dining hall of Lehigh university. The afternoon business meeting will be held in the recreation building of the university, whose president, Dr. C. F. Richards, has offered these facilities to the Lehigh Valley chapter for the use of their guests. The excellent work at Lehigh university, in metallurgical, mining, chemical and other engineering courses is well known to the members of this society, and an opportunity to visit the university should be embraced by every member. At the time of the June meeting the university campus and its surroundings are especially attractive and

Hydraulic Forging Press—Capacity 5000 Tons

Main Office Building, Bethlehem Steel Co., Bethlehem, Pa.

Library of Lehigh University

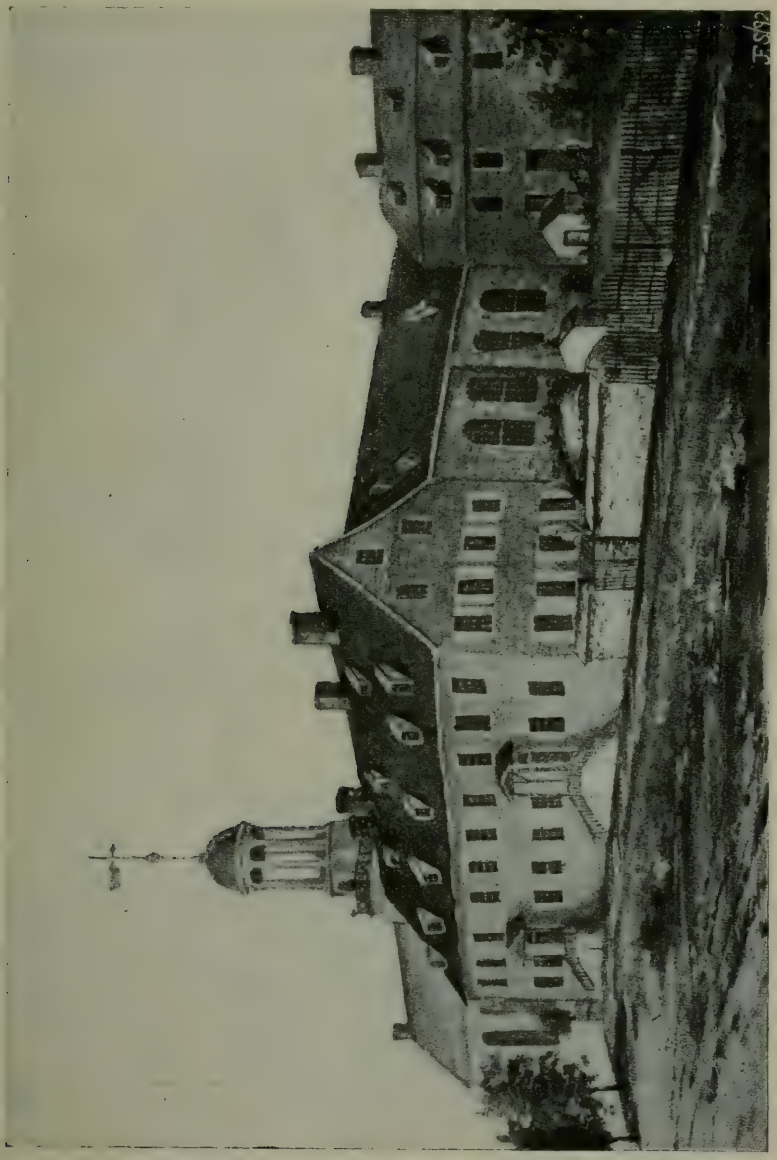
the sessions here will be a very pleasant experience to all who may attend.

The entertainment to be provided for the ladies as noted in the May issue of TRANSACTIONS, includes visits to many interesting points in the vicinity. Bethlehem is especially rich in historical associations, being founded nearly 200 years ago by Moravians who came here from Austria and Germany. Like many others of the early settlers of this country, they came seeking an opportunity for freedom in religious worship. For many years the customs of their country were maintained in their settlement, and the influence is still strongly felt. Even as early as Revolutionary times the customs of this community were known as distinctive, and many personages of note, as George Washington, Martha Washington, LaFayette, Benjamin Franklin, journeyed to Bethlehem and visited the places of interest. A deep interest in education was characteristic of the early settlers, and a number of schools were founded. Among these, the Moravian college for women enjoys the distinction

Parker Hall, Lehigh University, Where Business Meeting Will Be Held June 15

of being the oldest college for women in the United States, if not in the world. Some of the buildings still in use date back to 1742.

The auto trip planned, probably to the famous Delaware Water Gap, should be a very pleasant outing.



The Lehigh Valley chapter is making every effort toward holding an interesting and enjoyable meeting for its members and friends and all who can possibly do so are urged to attend the meeting.

Make hotel reservations with George C. Lilly, Superintendent of Heat Treating, Bethlehem Steel Company, Bethlehem, Pa.

DR. GEORGE K. BURGESS APPOINTED DIRECTOR OF THE BUREAU OF STANDARDS

THE Honorable Herbert Hoover, secretary of the department of commerce, under which department falls the United States bureau of standards, has announced the appointment of Dr. George K. Burgess as director of the bureau of standards at Washington.

Dr. Burgess has been associated with the bureau of standards for the past 20 years starting out as associate physicist in the year 1903. In 1913 he was appointed chief physicist and head of the division of metallurgy, which position he has held up to the present time.

In his 20 years of service, Dr. Burgess has aided very materially the rapid growth of the bureau which has expanded both in the number of building and laboratories constituting its physical make-up as well as the personnel and scope of the work which it is doing. The bureau stands very high in the technical and scientific fields and we are sure this high standard has been largely due to the work of Dr. Burgess.

In accepting the directorship of the bureau, Dr. Burgess assumes a grave responsibility, but one which he is perfectly capable of handling. He is assured of the most harmonious co-operation on the part of the men in the industrial field with whom for the most part he is personally acquainted.

It is with great satisfaction and pleasure that we have learned of this appointment and we wish to assure Dr. Burgess that he will have the sincere and hearty support of the American Society for Steel Treating in his new work.

Dr. Burgess has been a member of the society since its inception and has ardently supported it in its work during the past years.

We are looking forward to many notable accomplishments under the able guidance of the new director.

GUESSING VERSUS REASONING

THOSE who attended the annual convention of the American Society for Steel Treating held in Detroit last October will recall that a guessing contest was conducted by the Atlas Steel Corp. The contest called for the guessing of the nature of a steel which was exhibited. The exhibit consisted of five pieces of this steel, one showing the fracture, the other four showing polished cross-sections each etched with a different acid. First prize of $50.00 went to W. H. Blocksidge, metallurgist of the J. H. Williams Co., Buffalo, N. Y., second prize went to C. A. Smith, Coraopolis, Pa., and third prize went to Mrs. F. P. Gilligan, Hartford, Conn. The material was a piece of low-carbon bessemer steel.

	Carbon Per cent	Manganese Per cent	Silicon Per cent
Average analysis	0.13	0.58	0.03
First prize guess	0.17	0.60	0.09

The other guesses deviated interestingly from this, in many cases to automotive steels, spring steels and high speed steels. The reasoning

back of those guesses is not known, but it will perhaps be of interest to take advantage of the first prizewinner's permission to quote his reasoning.

"Upon examining the fracture of the bar, the average man would probably say that it was 0.60 per cent carbon steel, but on a little closer examination, he would observe a certain paleness in this fracture that is not common to a 0.60 per cent carbon steel, hence a question would arise. The light color of the metal etch would indicate one of two things, namely; a low carbon, or an alloy steel, probably high chrome. Next, the sulphuric acid etch indicated that it was not a high carbon alloy steel, but a low carbon product which might have been an alloy steel. The other etch exhibited considerable segregation in the bar, so by arguing that no reputable alloy steel mill would put out such segregated steel, it therefore, must be a low carbon plain steel.

"Being a low carbon steel, the fracture indicated that it was brittle. The question then arises as to what is the analysis of a low carbon brittle steel?. Most likely a bessemer steel; consequently, the average bessemer screw stock will run 0.17 per cent carbon, 0.60 per cent managese and low silicon, say 0.09 per cent—Presto and the prize."

FINANCIAL STATEMENT OF THE AMERICAN SOCIETY FOR STEEL TREATING FOR THE YEAR 1922

THE report of the auditors upon the result of their audit of the books of the society is submitted herewith.

Their statement shows that the society has not only lived within its income during the past year but has made substantial additions to its reserves and surplus.

The size to which the business of the society has grown is well illustrated by the fact that the "Income and Expense Statement" shows a turnover for the year of $75,000.

The sum of $3000 was set aside by the board of directors for the principal of the Henry Marion Howe Medal fund.

The sum of $10,000 was set aside by the board of directors from the proceeds of the Detroit convention as a permanent convention reserve in order to fortify the society against disaster from a financially unsuccessful convention.

The principal of these two funds has recently been invested in United States government bonds.

The full details of the auditor's report are on file at the society offices and are open to inspection of all interested members.

Signed—J. V. Emmons, Treasurer.

EXHIBIT A

BALANCE SHEET

AMERICAN SOCIETY FOR STEEL TREATING

December 30, 1922

ASSETS

CASH

The Cleveland Trust Co. (Commerical account)	$ 2,812.44	
The Cleveland Trust Co. (Savings account)	4,518.80	
The Equity Savings & Loan Co. (Savings account)	2,575.63	
The Union Trust Co. (Savings account)	1,040.40	$10,947.27

INVESTMENTS			
Euclid Village, Ohio 6% Water Bonds		$3,000.00	
U. S. Treasury Certificates		2,015.00	
Certificates of Deposit (Equity Savings & Loan)		9,500.00	$14,515.00
ACCOUNTS RECEIVABLE			
Advertsing	$ 2,972.62		
Detroit 1922 Convention	141.97		
Sundry Accounts & Advances	656.00	3,770.59	
Less—Reserve for Doubtful Accounts		1,000.00	2,770.59
Inventory paper & bindery stock			962.00
Furniture and fixtures (book value less depreciation)			1,235.62
Pittsburgh convention expense prepaid			960.83 $31,391.31
LIABILITIES RESERVES AND SURPLUS			
Accounts payable			393.87
Reserve for dues paid in advance			10,000.00
Permanent convention reserve			10,000.00
Henry Marion Howe Medal Fund			3,000.00
Surplus			7,997.44 31,391.31

CERTIFICATE

We have made an audit of the books and record of the AMERICAN SOCIETY FOR STEEL TREATING for the year ended December 30, 1922 and in our opinion, the above Balance Sheet—Exhibit A together with the annexed Income and Expense Statement—Exhibit B correctly present its financial status at December 30, 1922 and a history of its financial transactions for the period under review, basing the income from dues upon cash receipts and other income upon accruals.

Respectfully submitted,
NAU, RUSK & SWEARINGEN,
Certified Public Accountants.

EXHIBIT B

INCOME & EXPENSE STATEMENT
AMERICAN SOCIETY FOR STEEL TREATING
Year ending December 30, 1922.

INCOME			
Advertising			$ 19,909.54
Membership dues			27,714.64
Detroit 1922 convention			24,772.78
Transaction sales			985.90
Bindery sales			300.01
Reprint sales			384.90
Pins and buttons sales			28.00
Discount on purchases			83.35
Interest earned			798.93
Miscellaneous income			79.53
Collections (Accounts receivable previously written off)			23.80 $75,081.38
EXPENSES			
Returned to local chapters			10,051.95
Bindery			312.55
Reprints			286.81
Transactions			
Paper and cover stock	$2,263.64		
Printing	7,527.36		
Editor	2,730.00		
Editorial assistance	308.35		
Editorial traveling expense	238.05		
Clerical	837.95		
Commissions	618.60		
Cuts	1,407.85		
Postage	385.27		
Executive salary	1,500.00		
Rent	525.00		
Stationery	131.76		

Office supplies		$ 65.84	
Mailing and miscellaneous expense		223.87	$18,763.54
Secretaries' office			
Executive salary		2,400.00	
Rent		1,077.00	
Clerical		742.16	
Traveling		831.10	
Stationery		263.29	
Office supplies		154.88	
Postage		635.35	
Telephone, telegraph and miscellaneous office expense		664.23	6,768.01
President's office			
Traveling expense		775.59	
Telephone, telegraph and miscellaneous office expense		337.86	1,113.45
Treasurer's office			
Bookkeeper's salary		720.00	
Auditing		225.00	
Stationery, postage and miscellaneous expense		106.79	1,051.79
Detroit convention			
Convention expense—General		12,566.13	
Executive salary		2,100.00	14,666.13
Director's expense			
Traveling		1,355.16	
Miscellaneous		308.11	1,663.27
National committees			
Traveling		553.12	
Miscellaneous		67.31	620.43
Sectional meetings			
New York		400.02	
Pittsburgh		432.36	832.38
Increase of membership			771.98
Bad debts (including $200.00 added to reserve)			723.24
Discounts allowed			32.63
Bank exchange			3.04
Euclid village bond premium charged off			101.64
Incidentals			401.84
Balance disposed of as follows:			
Permanent convention reserve		10,000.00	
Henry Marion Howe Medal Fund		3,000.00	
Addition to reserve for prepaid dues		500.00	
Allowance for depreciation of furniture and fixtures		1,000.00	
Additon to surplus		2,416.70	16,916.70
			$75,081.38

NEW CHAPTER IN LOS ANGELES

ALL of the older chapters of the American Society for Steel Treating welcome the new arrival of a chapter from the land of sunshine and flowers and wish for it a continuance of the success with which it has so auspiciously begun its career.

In January, Charles P. Miller, associated with the Raymond G. Osborne Co., called together a number of interested individuals in Los Angeles and vicinity who had previously expressed the desire that something definite should be done in establishing a chapter of the American Society for Steel Treating. At this preliminary meeting an organization committee was formed of which Mr. Miller was elected acting-secretary.

A formal application for a charter was presented to the board of directors of the American Society for Steel Treating and acted upon favorably at their meeting on February 10.

On March 14, at the office of the Rich Steel Products Co., the

ROBERT B. DUNSMORE
Chairman—Los Angeles Chapter

E. C. LeMUNYON
Vice Chairman—Los Angeles Chapter

JAMES H. KNAPP
Sec'y-Treas.—Los Angeles Chapter

first and organization meeting of the Los Angeles chapter was held. This meeting was attended by twenty-three signers of the application for the chapter and was presided over temporarily by Mr. Fitzhugh as chairman with Mr. Miller acting as secretary.

After a general discussion of the purpose of the meeting and some very interesting remarks by some of the members of the society who had been connected with other chapters, the chairman called for nominations of chairman, vice chairman, secretary-treasurer and members of the executive committee to hold office until May, 1924. The following officers were elected:

Chairman

Robert B. Dunsmore, metallurgist

Vice Chairman

E. C. LeMunyon, vice president Rocky Mountain Steel Products Co.

Secretary-Treasurer

James H. Knapp, manufacturer's representative

Members of the Executive Committee

C. P. Miller, Raymond G. Osborne Co.
J. A. Baker, works manager Rich Steel Products Co.
James M. Fitzhugh, production manager Llewellyn Iron Works Torrance plant
Wm. W. Farrar, district manager, Ludlum Steel Co.
H. J. Barton, manager, Jamison Steel Co.

At this meeting it was decided to hold regular meetings on the first Wednesday of each month at 7:30 p. m.

Much credit is due to the older members of the society as well as as the new ones who have interested themselves in the formation of the local chapter, and judging from the caliber of the officers elected as well as the positions held by the members so far elected, the chapter has every possibility of having a very successful career and will fill a long needed position in the Los Angeles territory.

The officers and members of the Los Angeles chapter have the best wishes of the entire membership for continuing the successful work so far accomplished by the society, and express the hope that the chapter will take its place in the community as a real service and benefit to the iron and steel industry.

COARSE GRAINED DROP FORGINGS—THEIR DETECTION AND CORRECTION

By L. S. Cope

Abstract

As indicated in the title of this paper, the author has reviewed in considerable detail those factors which chiefly contribute to a coarse grained structure in drop forgings. Excessively high forging temperatures with an insufficient amount of mechanical work are the two main contributing factors to this condition.

Methods of detecting coarse grained fractures are discussed and the author describes a method devised by himself which has proven very satisfactory and one which can be expanded to a 100 per cent inspection of the product of a shop. Numerous illustrations are included in this paper as evidence of the practicability of the method.

The author discusses the various methods of heat treatment which are applied to coarse grained forgings in an endeavor to reclaim them for service, stating that most of the heat treatments used are "freak" treatments and are of little practical value. The importance of proper furnace design, proper heating temperatures and proper reductions in hammering the metal into the dies is of prime importance.

IT frequently happens that when examination is made of fractured hardened steel pieces which represent a batch of material just finished, it is found that several of the pieces are very coarse grained. Sometimes it is not until the hardened pieces are on their way through the plant being fabricated into finished articles, that one of them is accidently dropped on the floor, breaking into many pieces, revealing a very coarse grained fracture.

On the other hand perhaps the pieces have for some reason escaped the fracture inspection of the heat-treating department and have gone through the subsequent manufacturing processes without being ruptured and finally reach the ultimate user who puts them into service. Early failure occurs in service and typical broken pieces are returned to the manufacturer.

After examining the course fracture, the manufacturer probably sends a telegram to the "poor" steel manufacturer which which might read something like this:

> "Your steel coming very poorly. Fracture looks like sash-weight iron. Something must be done at once. Send representative."

The steel manufacturer is blamed for the faulty steel which caused this coarse grained and weak fracture and he in turn blames the heat treater, but the heat treater furnishes evidence that his pyrometer control, his furnaces, his fuel, etc., are ideal, and so a two-sided battle wages; with a third party, the foreman in charge of the forge shop continually supplying the ammunition for the battle.

It is not the purpose of the writer to convey the impression that all coarse grain in heat-treated steel pieces is due to faulty forging, but he does

A paper presented before a meeting of the Society. The author, L. S. Cope, is metallurgist with the National Screw & Mfg. Co., Cleveland, Ohio.

infer that faulty forging is directly responsible for a large percentage of the poor results obtained in the hardening or subsequent operations, whatever they may be. A piece of steel improperly forged will not respond to anything short of "freak" after-treatment, and if the piece is improperly forged it is in many cases ruined and cannot be reclaimed by any heat treatment. There are several "freak" methods of heat treating and partially reclaiming a faulty forging, but this should not justify faulty forging methods. If a man becomes ill, he can very often be cured by proper treatment and medicine, but it doesn't always follow that he is as healthy after the cure, as he would have been had he never become ill.

Many plants have specialists whose duty it is to carefully watch all heat treatment. To these men the writer would say "your duty is to watch the steel from the time it is introduced into the forge furnace, through its annealing, hardening and until it finally comes out of the tempering bath". It is just as important to investigate and correct and maintain proper forging heats as it is to maintain proper hardening heats. The one effort is useless without the other.

The Cause of Faulty Forgings

There are several things that happen in the forging operation to cause faulty forgings. Many hammermen are accustomed to working on steel made "mushy" and "plastic" by high furnace temperatures, and the forging is very often finished at high temperatures. If forging could be prolonged so that the finishing temperature is just a little above the critical range, it would then make little difference what the temperature of the bar was when it was taken from the forge furnace, as it is the finishing temperature which determines the quality of the forging.

It usually happens however, that the forged piece has to be completed in a given length of time, or in a given number of blows of the hammer. The metal has then filled up the cavities in the dies and to continue hammering further would merely result in the faces of the dies striking each other or striking the "flash" and doing little or no work on the forged piece. So it is not always possible to start with a very hot bar and prolong the working to a proper finishing temperature. In order, therefore, to adopt the practice of low finishing temperatures, we must likewise expect to heat the bars to lower initial temperatures, according to the size and character of the forging.

Fig. 1 is a diagram showing the effect of hot working upon the structure of steel. The two top parallel lines represent the solidification range. The middle pair of parallel lines represent the critical range and the bottom line represents atmospheric temperature. The width of the vertical band represents the size of the grain. In interpreting this diagram let us start with steel in the molten state as at "A". As it cools through the solidification range a coarse crystalline structure is formed, as represented by the distance between the two diverging lines starting from point "A". As the steel further cools the grain size gradually increases until the critical range is reached, when the grain size remains constant down to atmospheric temperature.

In studying this diagram bear in mind that it is the width of these vertical bands that represents the grain size and the cross hatched lines are merely for the purpose of darkening the bands. If we now reheat this "ingot" no change takes place in the grain size until the critical range is reached, at which time the grain size "tends" to decrease. Further heating above this critical range causes the grain size to again increase in size until

when point "B" is reached, the grain size is very course. Point "B" is what might be called the temperature and grain size of a bar which has been heated to a high temperature for forging.

As just stated, in heating through the critical range, the grain size "tends" to decrease, and this is really all it does do. Very course grain has

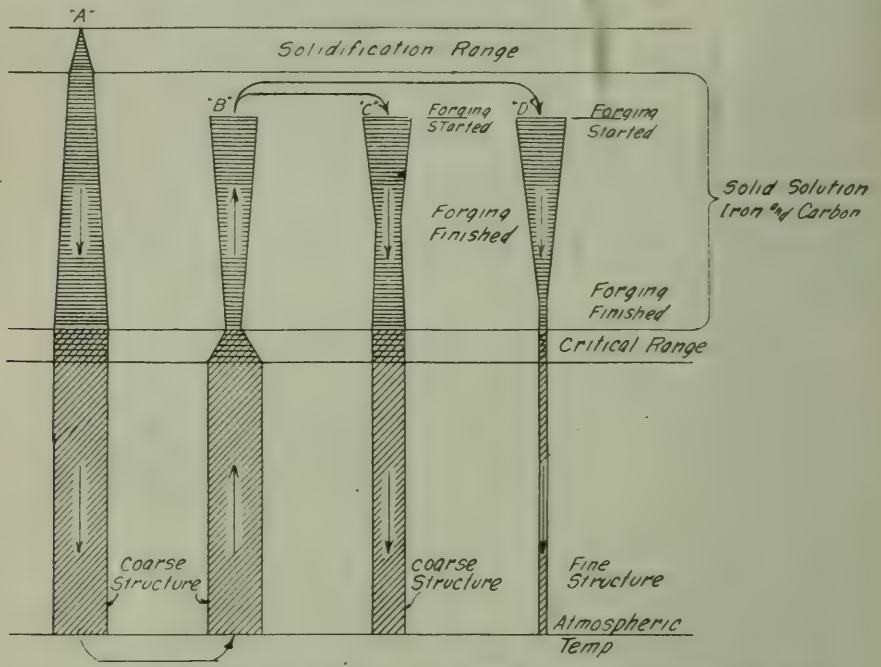


Fig. 1—Diagram Showing The Effect Of Hot Working Upon The Structure Of Steel.

a tendency to persist, even after prolonged annealing. If it were possible to break up "ingotism" (which is the common name given to the presence of very coarse grain in ingots) by a prolonged anneal, it would seem to be the proper thing for a manufacturer of milling cutters (for example) to buy round cast ingots and thoroughly anneal them, and then cut off discs and proceed to make milling cutters, knowing that he had avoided the steel mill rolling charges. All of which is absurd. The steel manufacturer rolls his material with two objects in view. First, to reduce the section and change it to the desired shape. Second, to reduce the grain size. No treatment, other than mechanical working will reduce this coarse grain size, so that it is fit for commercial purposes.

Let us study the diagram a little further. After the piece has been reheated to "B", suppose we withdraw it from the furnace and start hammering, and continue this hammering until a temperature of 1700 or 1750 degrees Fahr. is reached, after which hammering is stopped. The grain size has been somewhat reduced, although it is still coarse, and further cooling after the hammering is stopped, results in a growth of grain size until the critical range is reached, where the grain size becomes fixed and remains so down to atmospheric temperature. It is still coarse grained, although not quite as coarse as the ingot.

If we reheat this coarse grained forging we will find that we can par-

tially refine the grain by several "freak" methods, but after all, only partially. This forging "C" is virtually an "ingot" and shows signs of "ingotism". If, however, we forge as at "D" and finish just above and near the critical range, it is obvious that we obtain the maximum refinement of grain. We can now take the forging "C" and reforge it as at "D" which will result in refinement of the grain.

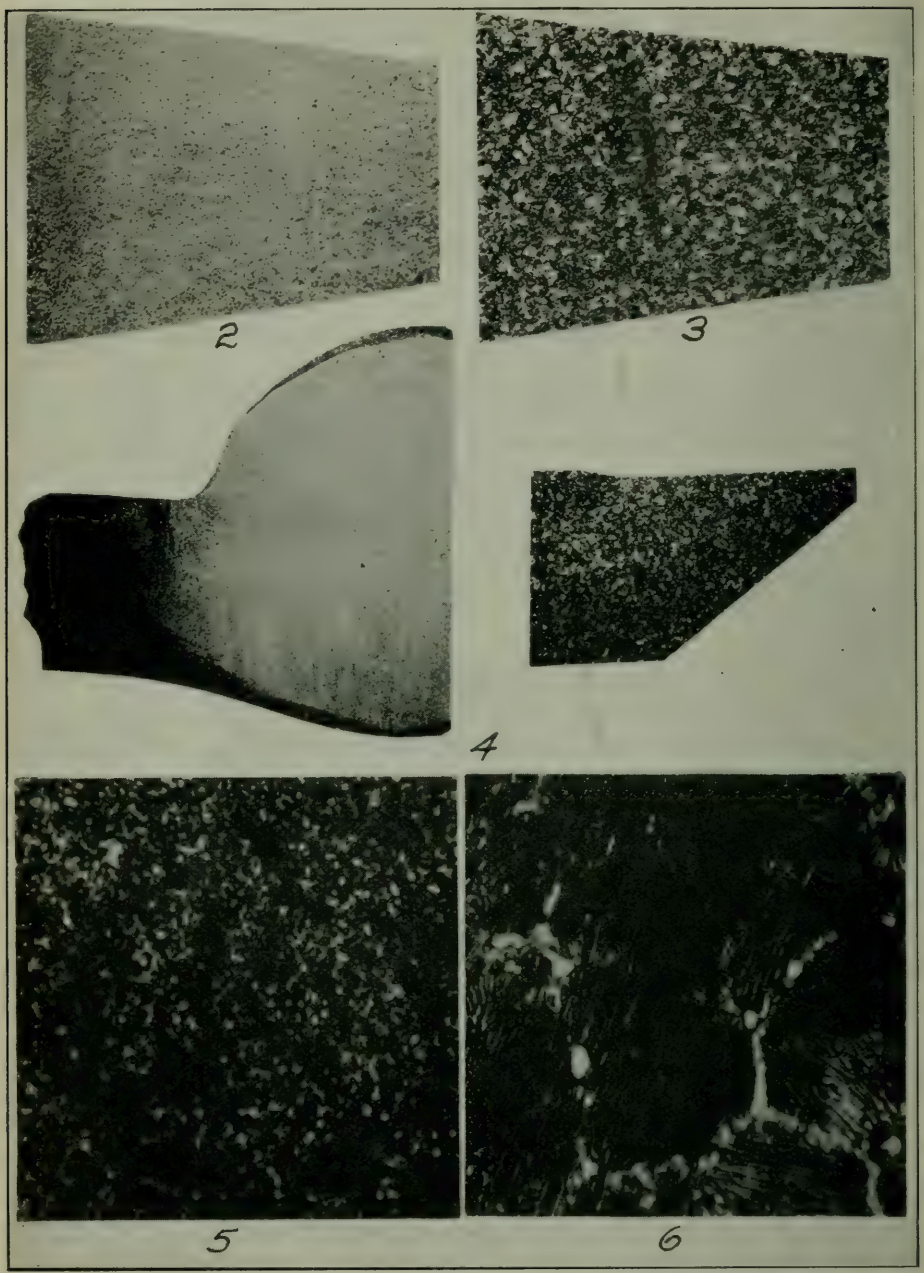
A forging manufacturer usually specifies hot rolled stock un-annealed. If the stock as received from the steel mill is in a slightly coarse grained condition, it would make but little difference, provided the manufacturer would conduct his forging at low finishing temperatures as at "D", and even though the steel mill supplied well annealed and fine grained stock, the forger would ruin it by high finishing temperatures as at "C". In the latter case the forger has virtually "recast" the good steel bar and remade it into an ingot which cannot be fully reclaimed by any treatment, other than rehammering or rerolling.

The forger cannot always be blamed for these conditions. In many cases his furnace equipment is quite inadequate. Sometimes he builds his own forge furnace, sometimes his furnace is purchased outside, but in either case the ordinary variety consists of a refractory box with a burner hole in one side and an opening in the front for inserting the bars to be heated. Then too, the working opening is usually too narrow and a high temperature must be maintained in the furnace to bring the bars up to forging temperature within the required time. Usually the temperatures are altogether too high and very nonuniform. The question of forge furnaces will be discussed later in this paper.

The Detection of Coarse Grain in Forgings

Under visual examination all forgings look practically alike, whether they have been finished at a high or low temperature. Sometimes one will find the very hot forging to be "scaled" more than the forging finished at relatively low temperatures, but the difference is not great enough to provide a positive means of detection. It is of course always possible to break a forging and study the fresh fracture, and also to prepare photomicrographs which will tell the story. The forged piece, however, may be an expensive one and for this reason the inspectors may be very reluctant to break it. Even if such inspection were made at the sacrifice of several forged pieces, this examination would be made on only a few pieces selected at random and would not assure the inspector that the forgings he had just passed or rejected were all exactly like the sample tested. In fact he might select one sample out of ten forgings, find that sample to be fine grained and put his O. K. on it, whereas 5 forgings out of the remaining 9 might be coarse grained. Studying the fracture or the photomicrograph are both positive means of determining whether the particular piece tested is overheated, or properly heated, and for the purpose of investigation are absolutely necessary. For the "control" of the product however, and for insuring the proper quality in every piece turned out, other means must be adopted.

The writer has found that a solution consisting of 2 parts of nitric acid and 3 parts of water, make a positive detector for coarse grain in forgings without in the least injuring the forging. The scale must first be removed from the forging or from a spot on the forging, or better still the etching operation can be performed after the forging has undergone its first milling, rough grinding or machining operation, which will lay bare the metallic surface and be well under the decarburized surface. The piece or pieces are



Figs. 2 and 3—Comparison Of Surfaces Of Fine and Coarse Grained Plier Jaws Etched In A 40 Per Cent Solution Of Nitric Acid x4. Fig. 4.—Comparison Of A Fine Grained Plier Handle And A Coarse Grained Jaw Surface Etched In A 40 Per Cent Solution Of Nitric Acid x2. Figs. 5 and 6—Photomicrographs Of Fine And Coarse Grained Pliers. x500.

immersed in this acid solution and allowed to remain there until a violent action takes place and brown fumes are liberated, after which the pieces are withdrawn, immediately washed in tap water, and the "scum" which collects on the etched surface wiped off. If some time elapses before these surfaces are examined, it may be advisable to give them a dip in an alkaline solution to neutralize the acid remaining on the surface after washing. It is not necessary to heat the acid solution to hasten the attack, because heat is generated by reaction as soon as the pieces are immersed. It is advisable to give the pieces a dip in boiling water after they are etched and wiped so that the surfaces will dry uniformly.

When all this has been done and the pieces examined it will be observed that some of the surfaces are dark and "mottled" and have the appearance of having been sprinkled with flakes of graphite, while other surfaces have a smooth dull gray appearance. The eye need not be trained to see this difference as there is almost as much contrast between them as there would be if one kind were black and the other white. Of course the question is, what does all this indicate? The answer is that it indicates that the pieces having dark "mottled" surfaces have been finished too hot in the forging, and the pieces with the dull gray surfaces have been forged at a temperature near the critical range. If one of the "mottled" pieces is fractured it will be found to have a "sash-weight iron" coarse fracture, but if one of the dull gray forgings is broken it will be found to be fine grained.

Figs. 2 and 3 show two plier jaws. Both of these jaws were etched in the nitric acid solution. Both were in the same bath and etched the same length of time. The jaw to the left is one of the dull gray variety. Subsequent breaking showed this jaw to be fine grained. The jaw to the right in Fig. 3 shows a "mottled" surface. Subsequent breaking showed this jaw to be very coarse grained. Fig. 4 shows the side view of a coarse grained jaw and a fine grained handle laid in juxtaposition for purpose of comparison. These were also etched in the nitric acid solution.

Fig. 5 shows a photomicrograph of the section of the fine grained plier jaw and Fig. 6 a photomicrograph of the section of the coarse grained plier jaw shown in Fig. 3. Both of these are magnified 500 times. Note the fine grain of the former with practically no cells and the coarse cellular structure of the latter.

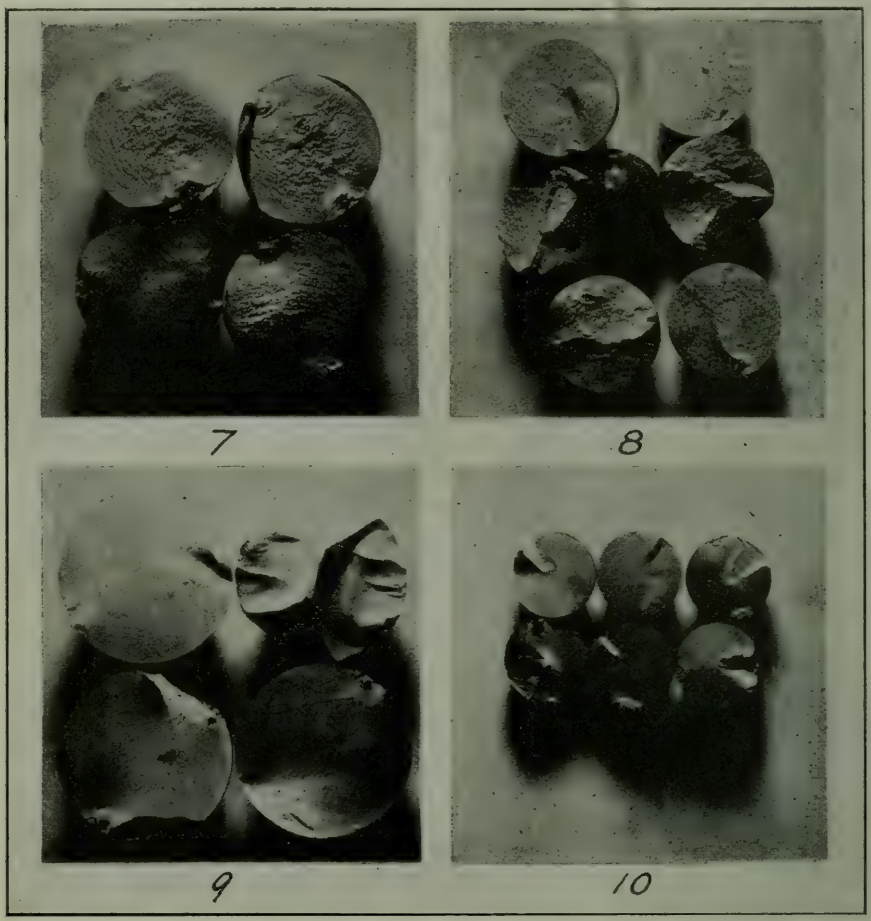
The writer has used this etching inspection successfully on 1.10 per cent carbon steel, on 1.00 per cent carbon, 1.50 chrome, ball bearing steel and on .80 per cent carbon steel. The plier jaws shown in Fig. 4 had a carbon content of .80 per cent.

Etching Test Easily Made

This etching test as a method of detecting coarse grain in forgings, is not a test which would necessarily have to be conducted in the laboratory or by the metallurgist. It is a thoroughly practical test which could be performed by the shop inspector or by the heat treating foreman. It requires little technique and little apparatus. It is not altogether impossible that this test could be made on every forging produced in the forge shop, as a part of production routine. In this event it would be necessary to have a tank of acid, a dipping basket impervious to acid, and an alkali bath. The entire production of forgings could then be etched and the "good" ones sorted from the "bad". The fact that the "good" forgings can be sorted from the

"bad" forgings by such a test does not warrant however a continuance of the use of a faulty forge furnace and faulty operations.

A better plan would be to first use the acid test on a certain percentage of the forgings as a means of investigating their condition, and then to correct



Figs. 7 and 8—Coarse Grained Fractures Of Balls Forged At Too High A Temperature.
Figs. 9 and 10—Fine Grained Fractures Of Balls Forged At The Proper Temperature.

the forge furnace conditions and lower the forging and finishing temperatures. After this has been done, the acid test could be used very advantageously as a means of controlling or checking the forging operation.

Photographs in Figs. 7 to 10 show groups of fractured hardened steel balls. Figs. 7 and 8 show coarse dry fractures. Such balls are very brittle and have a low crushing strength. Photographs in Figs. 9 and 10 show fine grained velvety fractures.

The practice in most ball plants is to fracture balls selected at random from the batch just hardened, as a check on the hardening heat. It does not follow that when a basket or pan full of balls are thus inspected, after hardening, that every ball in the pan will be found to be coarse grained, like those balls shown in Figs. 7 and 8. Perhaps 20 to 40 percent of them are

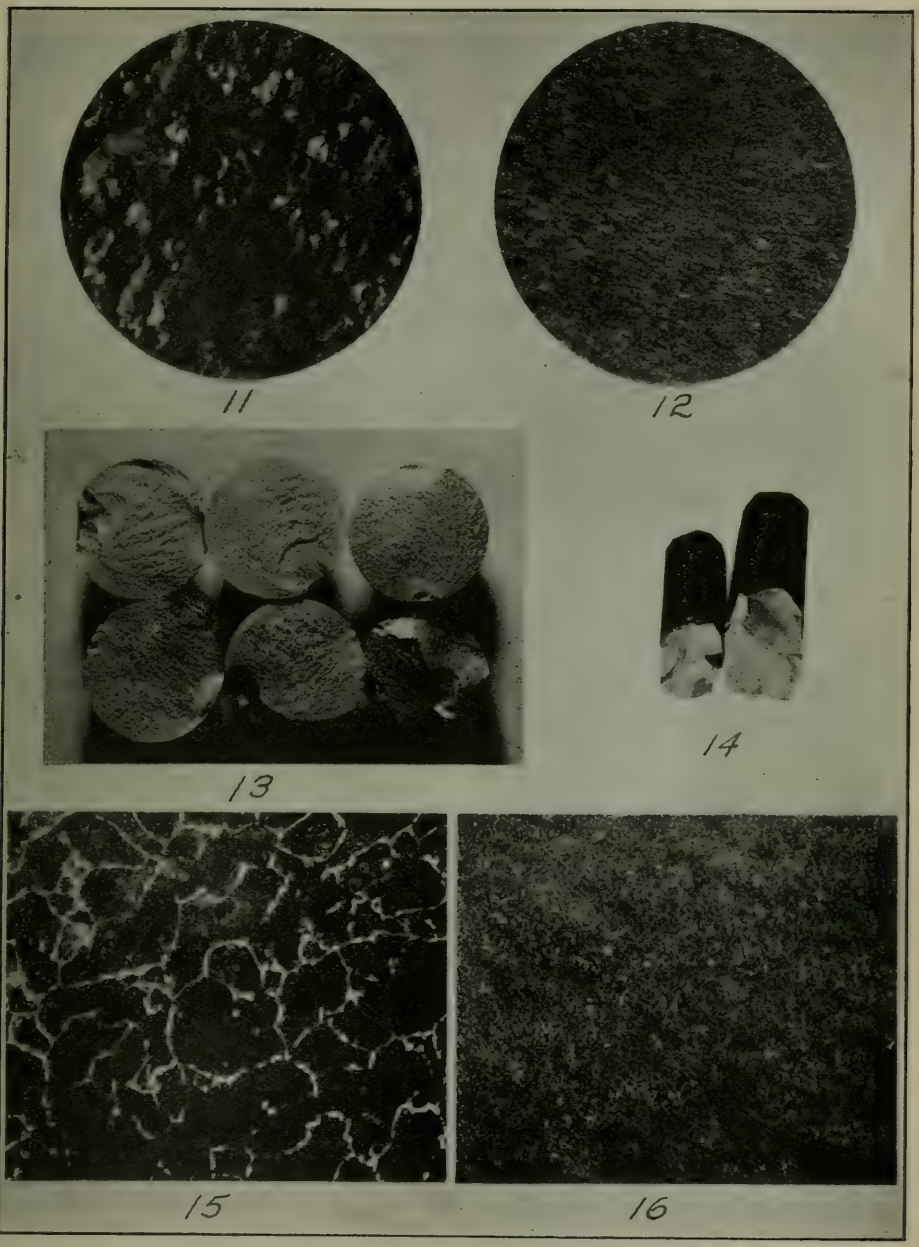


Fig. 11.—Fractures Of Balls Forged At Too High A Temperature. x50. Fig. 12.—Fractures Of Balls Forged At The Proper Temperature. x50. These Circles Represent Only A Portion Of The Broken Area Of The Balls. Fig. 13—Fractures Of Coarse Grained Balls Forged At Too High A Temperature. Fig. 14.—Two Of The Fractured Balls Shown In Fig. 13 After Rehammering To A Low Finishing Temperature. Fig. 15.—Typical Photomicrograph Of Overheated Balls, Fractures Of Which Are Shown In Fig. 13. x100. Fig. 16.—Photomicrograph Of The Properly Forged Pieces Shown In Fig. 14. x100.

coarse grained and the remainder fine grained and velvety, and the interesting part of it all is, that all this basket or pan full of balls were in the furnace together, heated together, and quenched together. It is hardly possible that such difference in fractures could be attributed to the lack of uniformity of heating in the chamber of the hardening furnace. A very thorough investigation in one of the ball plants definitely established the fact that the trouble started in the forge shop, and it was not until the forging equipment and methods were corrected, that the coarse grained fractures were eliminated.

With the forging shop continually overheating the steel, the hardening operation is usually nothing more or less than a futile attempt to put something into the steel which the forger has taken out.

Fig. 11 shows the natural fracture of a coarse grained ball such as shown in Figs. 7 and 8 magnified 50 times. Fig. 12 shows by comparison a fine grained ball such as shown in Figs. 9 and 10. These circles do not represent the outside diameter of the ball, but are simply portions of the fracture which were printed under a circular mat.

Figs. 13 and 14 illustrate one of the "freak" methods of reclaiming overheated ball forgings, of which we have previously spoken. Fig. 13 shows the fractures of a group of balls forged at a very high finishing temperature. Two of these balls were taken and reheated and reforged until the temperature was just slightly above the critical point and then hardened. These forged pieces are shown in Fig. 14. This shows that reworking at a low temperature will refine a coarse grained forging, but all this is interesting only from the metallurgist's point of view. It may be rightly called a "freak" method because it is not possible of commercial application. If a piece has already been forged and brought down to shape, to reforge it would merely mean to lay it in the cavities of the hammer dies and let the faces of the dies play against each other. The piece would not in reality be worked at all. The forger often becomes a steel manufacturer in that he takes a perfectly good piece of rolled steel, heats it up almost to the melting point, and in a sense "recasts" it into an "ingot" and nothing short of rerolling or rehammering will remove the ingotism or coarse grain.

Fig. 15 is a photomicrograph of one of the coarse grained balls shown in Fig. 13. Fig. 16 shows the micro-structure of the same ball after rehammering at a low temperature. Both of these photomicrographs were taken at 100 diameters magnification. There can be little question about the grain structure and relative strength of these two pieces.

Refining the Grain by Repeated Quenchings

D. K. Bullens[1] states, "when the initial structure shows a coarse grain size and overheating, the factors of diffusion and equalization become paramount, so that prolonged saturation, or repeated hardening must be used". He mentions a 10-inch diameter shaft having a coarse initial structure, requiring four quenchings to entirely sorbitize the steel, which is the same as saying "to refine the grain". This the writer classifies as only another "freak" reclaiming treatment, interesting only to the metallurgist.

Annealing and Normalizing

The purpose of annealing is to soften and put it in a machinable condition, and also to refine the grain. If a piece of steel has an initial structure of medium refinement, upon heating that piece above the critical point, and holding it there for a few hours and then cooling slowly, it is

[1] "Steel and Its Heat Treatment" by D. K. Bullins.

found that the maximum refinement has taken place. This form of heat treatment is called "annealing". In steel which is severely overheated and in a coarse grained condition, however, the old structure has a tendency to persist, even after prolonged annealing and slow cooling, and tends to lag behind and come back to its initial structure.

Fig. 17 shows a photomicrograph of the structure of a bar of very

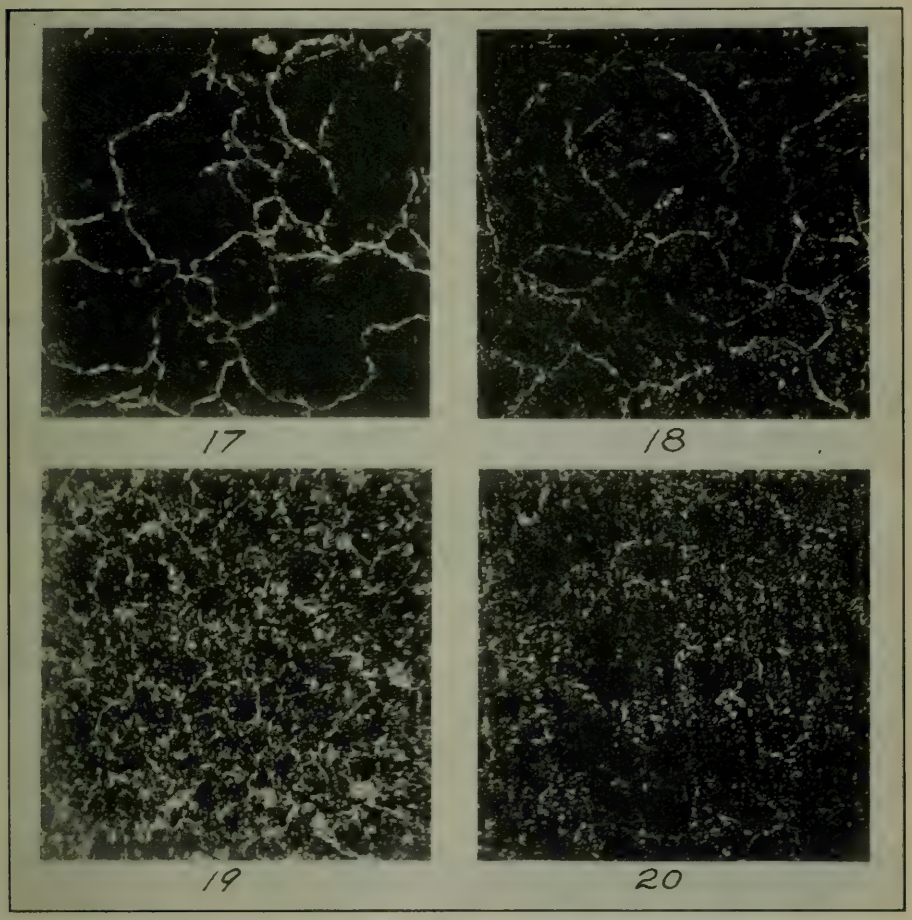


Fig. 17—Photomicrograph Of A Coarse Grained Hot Rolled Bar As Received From Mill. x150. Fig. 18—Photomicrograph Of The Same Bar After Annealing For 10 Hours At 1450 Degrees Fahr. x150. Fig. 19—Photomicrograph Of The Same Bar After Normalizing At 1650-1700 degrees Fahr. x150. Fig. 20—Photomicrograph Of A Fine Grained Hot Rolled Bar As Received From Mill. x150.

coarse grained steel as received from the steel mill when magnified 150 diameters. Fig. 18 at the same magnification shows the same piece of steel, but after a prolonged annealing just above the upper critical range followed by slow cooling. There is a tendency to form a new structure by this annealing, but also a tendency of the old structure to persist.

If, however, the piece is heated 250 to 300 degrees Fahr. higher than the upper critical point, held there for just a short time and then cooled in a free circulation of air, it will be found that the grain is partially refined.

This latter treatment is called "normalizing". Fig. 19 magnified 150 times shows the structure of the bar, after normalizing. This structure is much finer grained than either the "as received structure" or the "annealed structure", but the original coarse grain still tends to persist. This partial refinement of the grain by normalizing is due to the fact that the molecular changes take place more rapidly at the higher temperature and the tendency to lag is lessened, and owing to the fact that the normalized piece is cooled in air the molecules are prevented from returning to their initial state. This normalizing is usually followed by an anneal just above the critical point, the purpose of which is to soften it for machining operations. Fig. 20 shows the structure of a fine grained bar as received from the steel mills. While the normalized structure Fig. 19 is considerably finer than the "as received structure" Fig. 17, it is not as fine as the steel bar properly refined as shown in Fig. 20.

Normalizing is at best only a makeshift but comes nearer being a corrective treatment than any of the "freak" treatments previously described. A properly forged piece need not be normalized. A piece forged at too high a temperature can be only partly refined by normalizing. The fact that a piece can be normalized therefore does not justify faulty forging methods.

In the case of large forgings made on the steam drop or board drop hammer, or where the forged piece is of intricate shape, it is sometimes necessary to work at high temperatures in order to have the metal fill all parts of the dies. In the case of such forgings, it is always advisable to normalize and then follow by an annealing treatment.

In writing this paper the writer has principally in mind such forged articles as steel balls, pliers, scissors, cutlery, drills and the like, which are usually made on a helve or strap hammer. It is not improbable that some of the data will apply also on steam or board drop hammer work.

As previously stated Fig. 17 shows the structure of a coarse grained bar as received from the steel mill. The steel mills are not always exempt from the troubles arising from high forging or rolling temperatures. Of course the steel mill can bring about the structure shown in this photomicrograph by over-annealing as well. If the forging manufacturer forges this steel the initial structure as received will not have much effect, but if he buys so called annealed stock and it is coarse grained he will have endless trouble in the hardening room.

Fig. 21 shows a ball bearing ring from a coarse grained bar which was subjected to pressure. It bent very little and then broke. The bottom ring shown in this figure was made from a fine grained bar. It bent almost flat on itself and did not break. These rings have been etched in the 40 percent nitric acid solution and show respectively the mottled and dull gray surfaces. Fig. 22 shows the surfaces of these two rings as they came from the automatic machines. Note that the cutting tool has torn and glazed the surface of the ring from the coarse grained bar, while the surface of the fine grained ring has been machined with a clean even cut. One need have little imagination to conceive of what happens to the tools when these coarse grained rings are machined.

These photographs are interesting in that they illustrate the brittleness and hardness of coarse grained structures as compared with fine grained structures. These coarse grained structures are caused by a segregation of cementite. Cementite is the hardest constituent in steel. H. M. Howe[2]

2. "The Metallography Of Steel And Cast Iron" by H. M. Howe.

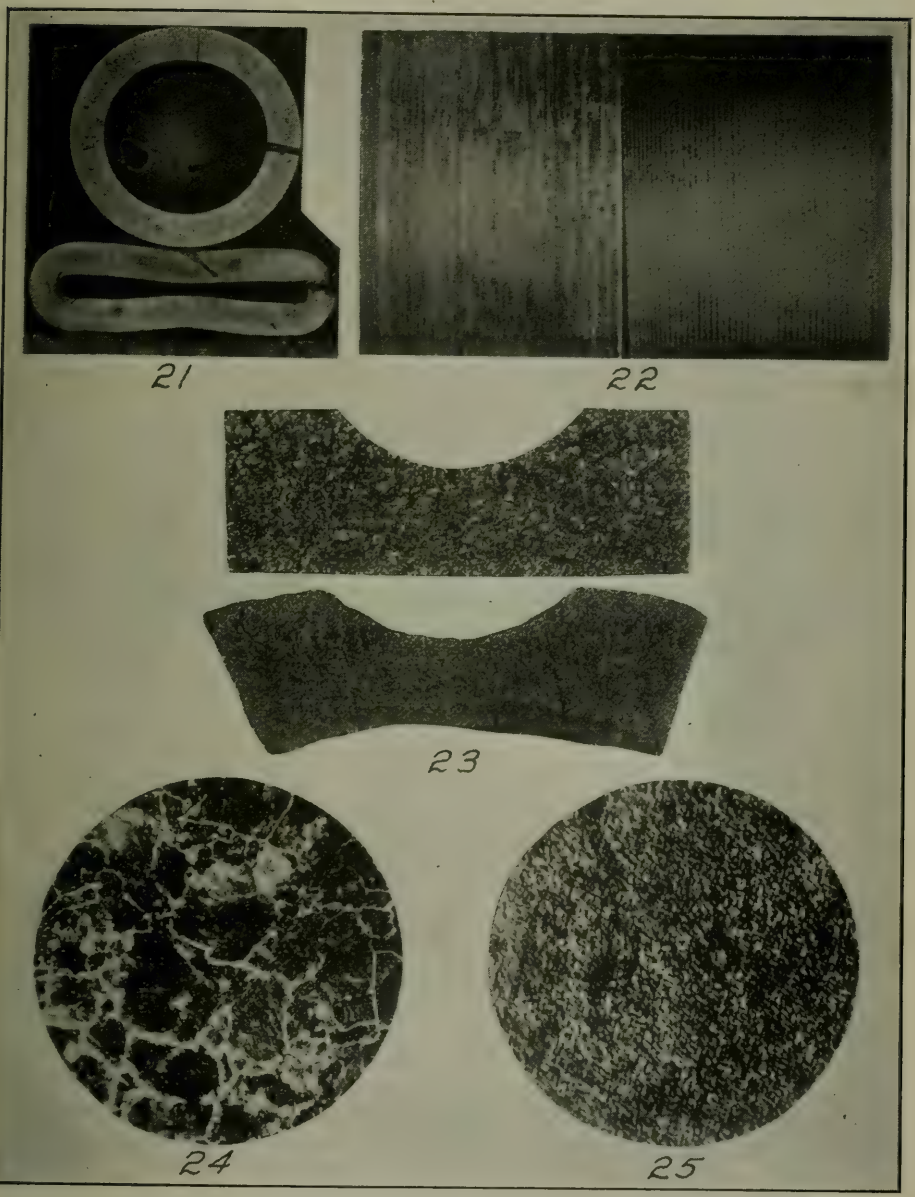


Fig. 21—Ball Bearing Rings. The Upper Ring Was Made From A Coarse Grained Bar And The Flattened Ring Was Made From A Fine Grained Bar. Upon Flattening The Upper Ring It Bent Very Little Before It Broke. Fig. 22—Photograph Of The Surface Of The Rings Shown In Fig. 21 Showing How The Turning Tool Tears And Glazes Over On The Coarse Grained Bar While The Fine Grained Bar Machines With A Smooth Even Cut. Fig. 23—The Upper Section Is That Of A Coarse Grained Fracture Of A Ball Ring While The Lower Section Is That Of A Fine Grained Fracture Of The Rings Respectively Of Fig. 21 x 100. The Two Black Bands On The Right Side Of The Rings In Fig. 21 Are Cords Which Carried Identification Tags And Are Not Cracks.

states "it is harder than glass and nearly as brittle". This may account for the fact that one of the drill manufacturers finds that a coarse grained steel with a Brinell hardness of 200 is more difficult to machine than fine grained steel with a Brinell hardness of 225.

Fig. 23 shows the natural fracture of the coarse and fine grained rings

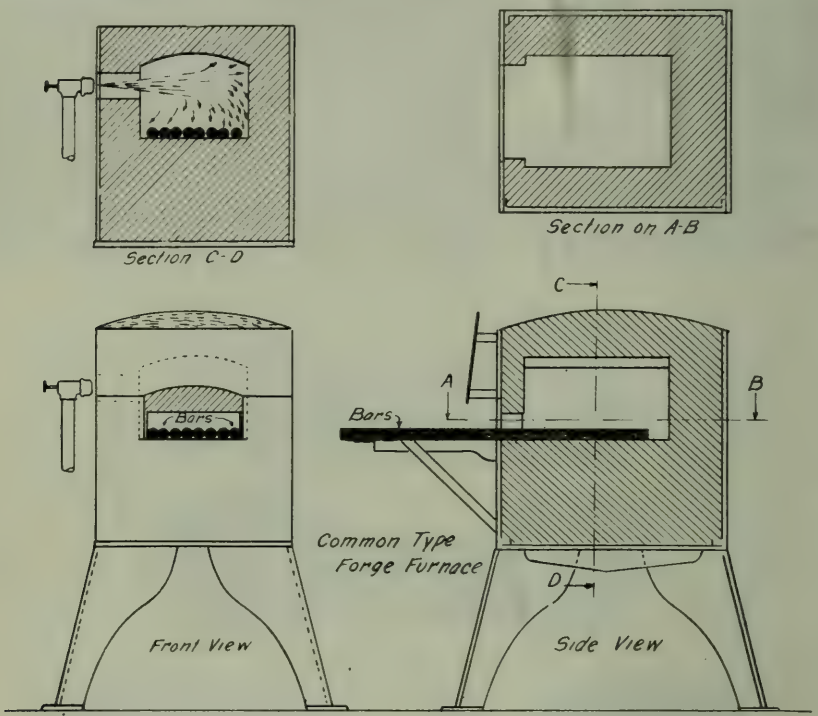


Fig. 26—Common Type Of Forge Furnace Usually Found In Forge Shops.

shown in Figs. 21 and 22. Fig. 24 shows a photomicrograph of the coarse grained structure, and Fig. 25 a photomicrograph of the fine grained structure. Both are magnified 100 times.

Forge Furnace Design

Fig. 26 shows the common type of forge furnace in use in most forge shops. It is nothing more than a box with a burner hole in one side and a working opening in the front for inserting the bars. The burner plays against one wall of the heating chamber as that is the only baffle wall it has to play against. The bars to be heated are laid on the floor of the furnace. Usually in a furnace of this type the working opening is too narrow and carries too few bars.

Let us assume that the furnace shown in Fig. 26 carries 8 bars of steel bar stock as shown. Let us further assume that the entire forging operation, from the time the bar is taken from the forge furnace, finished under the hammer, and returned to the forge furnace, consumes one minute. It would then require 8 minutes to make forgings of each bar in the furnace and return again to bar 1. The temperature of the bar when it is returned to the forge furnace, after the forging operation, would probably be 1000 or 1200 degrees

Fahr., and possibly only heated for a few inches of length to this temperature.

All of this shows that the bars must be raised from a temperature of 1000 degrees Fahr. to a forging temperature of say 1800 or 1900 degrees Fahr. in 8 minutes, which is a very rapid rate of heating and the only way to accomplish this rapid rate is to have a super-heated heating chamber. When working under such conditions, suppose that the hammer man is a little

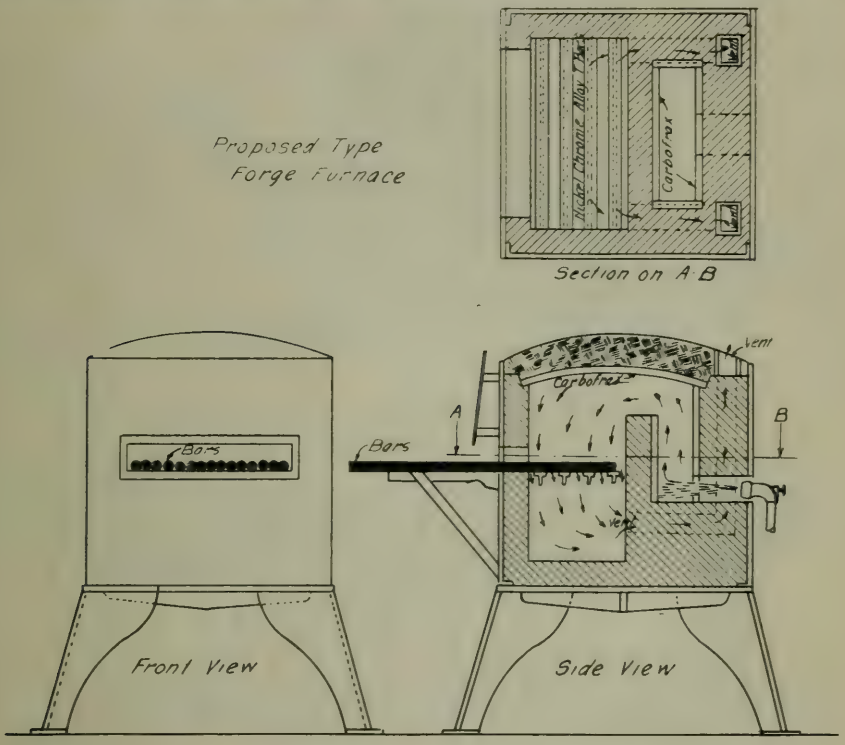


Fig. 27—A Proposed Type Of Forge Furnace Designed To Eliminate Some Of The Objectionable Features Of The Type Shown In Fig. 26.

delayed on making one of the forgings, or suppose he has to make a burner adjustment, or something of that kind, the cycle of events is disturbed and the next bar or bars have tried to catch up to the super-heated furnace temperature. Then too, in a furnace of this kind where the burner plays against the opposite wall, the bars on that side are heated very much hotter than the bars on the side of the furnace adjacent to the burner. Not only is such a furnace inducive to high heats, but it is also inducive to very un-uniform high heats. The furnace as shown is not the worst type of forge furnace in use, but it is the common type to be found in many forge shops.

Fig. 27 shows a proposed type of forge furnace, designed to eliminate some of the objectionable features of the furnace shown in Fig. 26. The writer has designed and built several furnaces of this type and the operation of them was satisfactory, although he does not make the claim that this is the only type of furnace that will overcome the objectionable features, as there are many other ways of making furnaces with baffle walls, combustion chambers, vents and what not. Also no claim could be made as to the

efficiency of this furnace, so far as fuel consumption is concerned. It would probably burn more oil than the common type of furnace, but it would surely burn less "steel." The furnace shown in this figure consists of a combustion chamber and a heating or working chamber. The baffle wall shown, runs across the entire width of the furnace. The bars to be heated project into the middle of the heating chamber, rather than lying on the floor of the

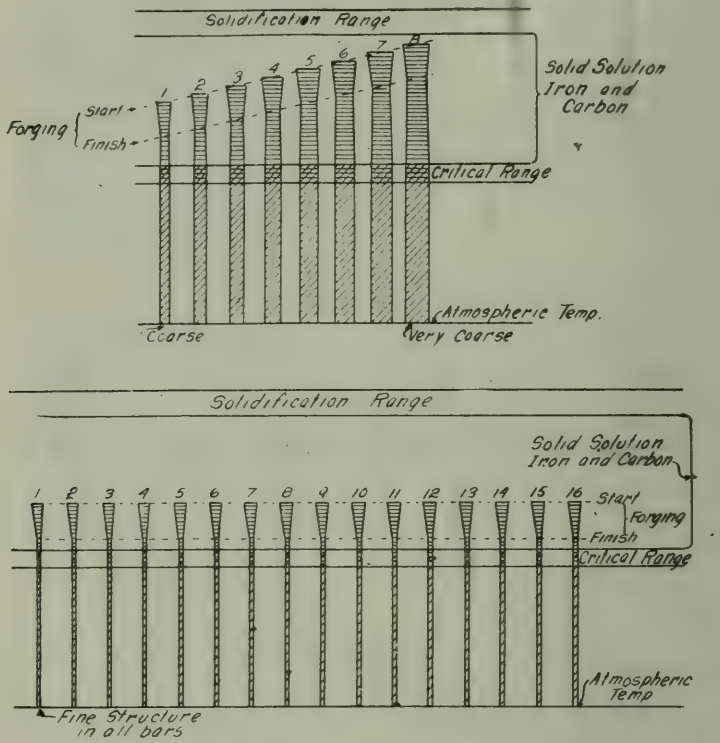


Fig. 28—The Upper Portion Of This Diagram Shows What Happens To The 8 Nonuniformly Heated Bars In The Common Type Forge Furnace, After Conducting Forging At A High Finishing Heat. The Resulting Fractures Can Be Anything From Medium Coarse To Very Coarse. The Lower Half Of Fig. 28 Shows The More Ideal Condition Of Grain Structure Which Would Result When Heating Twice As Many Bars In A Forge Furnace Of The Proper Design.

heating chamber as in the common type. Several vents are built in the back wall of the forge to provide an escape for waste gases and to direct the hot gases during their passage through the furnace. The result is a passage of the hot gases through the bars and a very uniform heating chamber results, by reason of combustion having taken place in a separate chamber. To provide for the stub ends of bars a grid of a heat resisting alloy or refractory is provided as shown. Note that this furnace has a working opening which will permit of the heating of 16 bars. It would therefore require 16 minutes to make a forging from all bars in the furnace, as against 8 minutes in the type as shown in Fig. 28. This allows more time for heating each bar and the heating chamber can be kept down to a temperature more nearly like the working temperature .

If the same delays in the forging operations occur, it will not do the bars any harm to soak for a short time. In fact a soak for a relatively long

period of time in this furnace would not do as much harm to the steel as a short period of heating at high temperature in the common type forge.

The width of a furnace working opening should be designed with respect to:

a. Length of time required to make a forging
b. The diameter of stock used
c. The temperature of the heating chamber.

The writer has in mind a furnace of this type which was built for heating bars for a "bulldozer". This furnace was 12 feet long with a baffle wall running the entire length of the furnace and 3 oil burners provided at the back. Every part of this heating chamber was uniform in temperature and it was almost impossible to "burn" the bars, but always possible to obtain sufficient heat for proper forging conditions.

Fig. 28, upper portion shows what happens to the 8 un-uniformly heated bars in the common forge, after conducting the forging at a high finishing temperature. The resulting fractures can be anything from medium coarse to very coarse. The lower half of Fig. 28 shows the more ideal condition of grain structure, which would result when heating twice as many bars in a forge furnace of the proper design. These diagrams need no further explanation.

Conclusion

In conclusion the writer wishes to emphasize that the question of proper forging has been neglected too long and it is high time that we give the same consideration to the forging furnace equipment and methods of operation, as we give to the annealing and hardening equipment and operation.

COMBUSTION AS IT PERTAINS TO INDUSTRIAL HEAT TREATMENT FURNACES

By A. D. Frydendall

Abstract

This paper treats with the subject of combustion as it pertains to industrial heating of materials. The author having had many years' experience in the design and operation of industrial heating furnaces has handled the subject from both a practical and theoretical standpoint discussing in some detail those points which are of prime importance in the efficient combustion of fuels.

He discusses flames, both luminous and nonluminous, as they are met with in the use of the common fuel gases.

The various types of fuels which are commonly met with and used in industrial heating are treated in considerable detail and the author has pointed out the advantages and disadvantages in the use of the various types.

In conclusion he brings out those points which are of prime importance in the efficient operation and handling of fuels in heating materials. These points include furnace design, burner design and burner operation, pointing out that the burners should be of such design and operation as to insure the intimate mixture of fuel and air so that only that amount of fuel that can be completely burned in the furnace chamber should be allowed to pass the burners. The furnaces should be correctly proportioned for the work they are to perform. Through the knowledge of the laws of combustion any furnace operator could obtain a substantial saving in fuel consumption.

THE subject of combustion, as it pertains to industrial furnaces, is not generally being given the consideration to which it is entitled. In the boiler room of a plant the subject is a familiar one, and the importance of it is emphasized by the many devices seen in the modern boiler room to assist those in charge in maintaining the correct conditions for high efficiency.

If you will step into the heat-treating room or forge shop of that same concern, you will find operators trying to maintain accurate temperatures and correct atmospheric conditions in furnaces where hundreds of dollars worth of material is heat treated every day, with nothing to guide them in their work but the colored lights of the pyrometer system. It is a common sight to see furnaces equipped with shutters and dampers for controlling the combustion, only to find that the operator does not know how to use them and does not care enough to learn. There are few furnaces today which, when properly operated would not show a neat saving in fuel and refractories when totalled up for a year's operation.

A thorough knowledge of the science of combustion is not necessary to insure practical success, but other things being equal, the man who has mastered the principles of combustion and applies them in his daily work, has a greater chance of making a success in his chosen field

A paper presented before a meeting of the society. The author, A. D. Frydendall, is associated with the Peoples Gas Co., Chicago, Ill.

than does the man who neglects the theoretical side of his education. A knowledge of both the practical and theoretical side is necessary for a well rounded education, and theory modified to conform with practice, is a big assistance to any man. It is not the purpose of this paper to go deeply into the theory of combustion, or to give a table showing the physical properties of the various fuels, but rather to outline the fundamental principles involved. Any discussion of combustion must be somewhat technical, but an effort will be made to treat the matter as simply as possible.

Combustion Defined

For our purpose, combustion may be defined as the chemical union of two substances taking place with sufficient energy to develop heat. In order that this chemical reaction may take place, it is necessary for the substances entering into the combustion to be above their combining or ignition point.

The most common substances used for fuel are complex compounds consisting mostly of carbon and hydrogen, with small amounts of sulphur, oxygen and nitrogen. Other constituents may be present, but they may be neglected without interfering with the principles under discussion or their practical application. These compounds of carbon and hydrogen may be used in either the solid, liquid or gaseous form, but no matter what form is used, they are governed by the same general principles.

These fuels unite with oxygen to produce the effect of heat as laid down in our definition. Oxygen abounds in the air where it is mixed with nitrogen in the proportions of 21 volumes of oxygen to 79 volumes of nitrogen. It is the oxygen of the air that supports combustion—the nitrogen serving no good purpose, in fact it is a detriment, as it reduces flame temperatures and necessitates larger flues and equipment to handle it.

Flames

To the average mind combustion suggests flame. Flame is a gaseous mass in the process of combustion. The condition necessary for flaming is that both substances entering into combustion be in the gaseous or vapor state. In the combustion of solid or liquid fuels where flame exists, it is caused by the gaseous products which are distilled from the solid matter, or produced by chemical action, entering into combination with air, thus producing flame. Flames may be classified as luminous and nonluminous and short and long. As examples of luminous flames, we might cite any of the hydrocarbons such as bituminous coal oil and acetylene.

Luminous and Nonluminous Flames

Nonluminous flames are met with when dealing with the common gases such as artificial gas, producer gas, water gas, hydrogen and natural gas. As a rule a nonluminous flame is harder to control than is a luminous flame, because the operator cannot see the flame, as is the case when working with luminous flames.

Luminosity in flames may be ascribed to three causes:

1. The temperature of the flame
2. The density of the gases composing the flame
3. The introduction of solid matter into the flame.

The effect of flame temperature and luminosity may be observed by holding a gas jet in contact with a cold plate and noting its diminished luminosity; on the other hand, if the gas and air are strongly heated before combustion takes place, the luminosity is greatly increased. There are exceptions to this rule, and the most common one is the hydrogen flame. Since combustion in furnace problems is always carried on at atmospheric pressure, the second cause of luminosity, namely, the density of the common gases composing the flame may be neglected. The third cause of luminosity may best be illustrated by the familiar gas light in which a mantle consisting of metallic oxides is raised to incandescence by introducing it into a nonluminous Bunsen flame.

The combustion of a liquid hydrocarbon, such as oil, is exceedingly complicated, and the decompositions which are peculiar to this fuel not only give off dense vapors which become incandescent, but also precipitates carbon, which by the combustion, adds to the luminosity of the flame. Since the luminosity of a flame is dependent on the temperature, it is possible to judge roughly the flame temperature by the flame color. Closely associated with luminosity is transparency, and it may be said that nonluminous flames are transparent flames, while luminous flames are opaque.

Flames may be either long or short, depending upon the rate of fuel consumption, the affinity of the fuel for oxygen, and the thorough mixing of the fuel and air. As a rule, long flames are low temperature flames and are the result of an improper mixture of fuel and air. Short flames on the other hand, are the result of a thorough mixture of the fuel and air, and are high temperature flames. From this it follows that short, high temperature flames indicate good combustive conditions.

Heat of Combustion

The other idea associated with combustion is heat, and that is the important thing in industrial furnace operation. The amount of heat developed in the combustion of any particular fuel measured in B.t.u's. is dependent upon heat of combustion of the fuel and the final products formed. The total amount of heat developed by the burning of any fuel is independent of the speed of combustion, and is the same, provided always the same final products are formed. As an example—let us take one pound of carbon which is completely burned to carbon dioxide—then 14,500 B.t.u.'s will be liberated. This pound of carbon may be consumed in one hour or in ten minutes, but in each case the heat liberated is the same. If, however, combustion is incomplete and carbon monoxide is formed, then only 4380 B.t.u.'s, or one-third of the total heat of the fuel, will be produced—the remaining 10,120 B.t.u.'s or two-thirds, will be liberated when the CO is consumed. This shows the necessity for complete combustion if we are to utilize the entire heat of the fuel.

Of equal importance to the heat developed is the temperature attained, or as it is more commonly called, the flame temperature. This depends upon several things, namely: The B.t.u. value of the fuel, the final products formed and the rapidity with which combustion takes place. Theoretically, it is assumed that combustion is instantaneous and complete, that there are no radiation losses, from the boundary

walls, that there is no dissociation, that the inert gases do not enter into the reaction, and that all of the heat of the fuel is used to raise the temperature of the products of combustion. Theoretical flame temperatures are never realized in practice, but are useful in determining the suitability of a fuel for any given operation. As an example, a producer gas showing the following composition:

Hydrogen	10 per cent
Methane	3 per cent
Acetylene	5 per cent
Carbon Monoxide	23 per cent
Oxygen	5 per cent
Carbon Dioxide	5 per cent

when burned with cold air has a theoretical flame temperature of 2832 degrees Fahr. which is reduced by certain factors in practice to about 2000 degrees Fahr. This temperature is insufficient to melt steel, and any attempt to use it in that manner would meet with failure as temperatures exceeding 3000 degrees Fahr. are required. Producer gas, however, when properly assisted by preheating both gas and air is being used daily for that purpose.

In practice, theoretical flame temperatures are reduced because combustion is not instantaneous—the walls of the furnace also absorb heat, and combustion is either not complete or else is accompanied with an excess of air, and air in excess of that required for combustion means low flame temperatures and high flue gas losses. From the foregoing, it would seem that any device which would permit an intimate mixture of the fuel and air in controllable quantities would function properly, but the great variety of stokers, oil burners and gas burners on the market are evidence that such conditions are not easily accomplished.

Specific Fuels

Passing on to specific fuels, we will apply our principles in turn to solid, liquid and gaseous fuels dwelling particularly on liquid fuel as there are several points possessed by it not common to the other fuels, as well as those common to all fuels.

Coke and Anthracite Coal

With solid substances for fuel, which are nearly pure carbon, such as coke or anthracite coal, these rules are easily applied, as each carbon atom is held in place until it has received the necessary two atoms of oxygen for combustion, after which it passes off as carbon dioxide. Were it not for the possible formation of carbon monoxide no greater space than that necessary to contain the fuel would be required for complete combustion. The concentrated heat of coke is made use of in the blast furnace and cupola where intense heat is wanted in small space.

Bituminous Coal

As we pass on to bituminous coal, a combination of carbon and hydrocarbon, the combustion becomes more difficult owing to the liberation of gases, which necessitates careful handling to insure complete and smokeless combustion. Owing to the gases set free, the combustion chamber must be larger than required for coke, to permit complete combustion within the chamber. The heat is not as concentrated as that of coke and for this reason coal is used in heating puddling and

metallurgical furnaces where a more general application of heat is desired than in the cupola or blast furnace.

The reactions going on in the fuel bed of a coal or coke-fired furnace deserve some consideration, especially as coal is the most generally used fuel. The fuel bed of the average coal-fired furnace may be divided into three active zones, in each of which a combustion reaction is going on. In the first or oxidizing zone, the oxygen of the air combines with the carbon in the fuel, and is converted into carbon dioxide in accordance with the chemical equations.

$$C + O_2 = CO_2$$

The depth of the oxidizing zone varies with the thickness of fuel bed; for a six-inch fuel bed and bituminous coal, it is about two or three inches. The carbon dioxide content in the oxidizing zone reaches a maximum of 12 to 18 per cent. In this zone the maximum temperature of 2200 to 2700 degrees Fahr. is also reached at a height corresponding to the maximum CO_2 content of the gas.

The second zone is the reduction zone, and it is in this zone that the CO_2 is reduced to CO. The reducing zone extends from the oxidizing zone to the top of the fuel bed. The amount of reduction varies with the temperature and the time of contact between the CO_2 and the hot carbon, the limiting feature being the temperature of the fuel bed.

The last or distillation zone, consists mostly of fresh fuel from which the volatile matter is being driven off by the heat. It is in this zone that hydrogen, methane, tar, soot and other hydrocarbons are liberated. This action is independent of the air passing into the furnace, and is similar in action to the destructive distillation of coal in gas retorts.

The percentage of combustible in the gases in the fuel bed increase steadily above the oxidation zone until at the surface of the fuel, a maximum of 15 to 30 per cent combustible gas and no free oxygen is shown. If no additional air is supplied above the fire, this combustible passes out of the stack unconsumed and it is for this reason that additional air for complete combustion must be added over the fire. In practice the fuel bed is seldom even, and additional air for combustion is furnished by holes and thin spots in the fire and leakage around doors and in the setting. This leakage is enough, in some cases, to furnish excess air over that required for combustion, thereby adding to the heat loss. The fuel bed of any coal-fired furnace is essentially a gas producer, and should be treated as such when considering the process of combustion.

Oil Fuel

Oil, as a fuel, is one of the most difficult to burn satisfactorily with good economy. Oil in bulk has little surface, and before it can be burned successfully, it is necessary to stretch or increase its surface enormously to permit the required number of oxygen atoms to come in contact with it to produce complete combustion. This increase in surface may be brought about in several ways, but the ones most in use are spraying, either with a steam or air jet, or by mechanical means.

At the very first we are met with difficulties, as the particles of

oil produced by the atomizing agent when freed from the force of gravity and under the force known as surface tension, assume the shape of a sphere which affords the least surface possible for the impact of oxygen atoms of any solid. To further complicate matters, these tiny spheres of oil are traveling at a high velocity towards the vent or stack. We see, therefore, that it is either necessary to provide a larger chamber or permit sufficient time for each atom of oil to reach the required amount of oxygen, or introduce means of hastening the mixture of oil and air to complete combustion within the furnace chamber. The speed of mixing may be increased:

First—By correct design of burner to more thoroughly atomize the oil.

Second—By introducing eddies in the fuel and the air stream.

Third—By initial heating of the air to increase the speed of diffusion.

There is one other action going on simultaneously with those already mentioned, that is, decomposition of the oil fuel.

The first effect of the heat is to dissociate the hydrogen from the carbon. It is these products of the decomposition of the oil, rather than the oil itself, that burn and produce the flame characteristic of oil fuel. The luminous part of the flame is caused by the white hot particles of carbon freed from their hydrogen components, and which have not yet reached the necessary air for combustion. If the temperature of these hot gases is kept above the point of ignition, until all the dissociated carbon is consumed, smokeless combustion is obtained. If, however, their temperature falls below the ignition point, smoke results. For this reason, fire brick walls and arches, when hot, assist in perfecting complete combustion.

Dissociation of the oil also manifests itself in another way. If raw oil is deposited on a hot surface, the liquid oil is decomposed, giving up gas and leaving as a residue, carbon in the form of coke. This coke is very hard and sometimes requires the use of cold chisel and hammer to remove and when thrown into a fire is consumed very slowly. It is for this reason that attempts to convert the oil into a gas before burning, have resulted mostly in failures, due to the retorts filling up with coke. This condition often develops in furnace practice due to the raw oil striking some portion of the heated brick work which decomposes the oil and deposits carbon.

In order that the high temperatures may be obtained, it is necessary that large quantities of fuel be consumed in a small space, and this requires a short flame. Conditions which assist in obtaining short flames are:

Pure carbon fuel

Intimate mixture of fuel and air to reduce time of diffusion

Preheating of air to increase rapidity of diffusion

Large fuel surface exposed to oxygen.

These rules are general and apply to any form of fuel. In addition to these we may consider a few others of special importance in the use of fuel oil:

a.—The volume of combustion chamber must be large—larger than for any other fuel

b.—The fuel must be exposed to the heat of the furnace in such

form that the largest possible surface is presented for vaporization of the oil and the impact of oxygen atoms

c.—The oil must spray freely into the furnace and burn without touching any portion of hot brick-work in its liquid form, as such would cause carbon deposits.

Gaseous Fuel

Turning now to gaseous fuel, and applying the principles as previously laid down, we find no problems such as found in the burning of oil fuel. Gas to start out with, is a stable substance and can be subjected to any conditions found in the heat-treating and forging furnaces without encountering any difficulties. As usually used, it is at atmospheric temperatures, and at pressures varying from two to six inches of water column.

In the burning of gas no matter whether lean producer gas or the rich natural gas, the main thing to be sought is an intimate mixture of the gas and air. Compared to oil this is easy, as we are dealing with comparatively large volumes and these large volumes can be regulated with a small percentage of error. The average gas flame is nonluminous and because of that fact requires closer observation to maintain the desired atmospheric conditions. Owing to the good mixture of fuel and air usually obtained with gaseous fuel, the flame of burning gas is short and combustion chambers need not be as large as is required for oil fuel. This advantage of short flames is also used in several so-called heating machines for continuous production where concentration of heat is desired.

Passing on to the application, or rather the lack of applications of these few simple principles of combustion to industrial furnaces, let us see where possible fuel savings may be made. One of the greatest losses in the operation of the average furnace is the flue-gas loss in excess air. The extent of this loss will vary with different fuels—it is largest with coal and least with gas, the loss being greater at high temperatures, decreasing as the working temperature decreases. A concrete example will better illustrate the point. Let us take an oil of the following analysis:

Carbon	84.0 per cent
Hydrogen	12.7 per cent
Oxygen	1.2 per cent
Sulphur	0.4 per cent
Nitrogen	1.7 per cent

For perfect combustion this will require 14.03 pounds of air per pound of oil, and at 1500 degrees Fahr. the heat carried away per pound of oil, by the products of perfect combustion is approximately 6250 B.t.u.'s. If now, instead of 14.03 pounds of air, an excess of 30 per cent is used, or a total of 18.23 pounds, then the flue-gas loss is 7840 B.t.u.'s, or an increase of 1590 B.t.u.'s, due to excess air. Suppose now the temperatures of the flue-gases leaving the furnace is 2200 degrees Fahr. such as might be the case in a forging furnace—then the loss per pound of oil with perfect combustion is 9630 B.t.u.'s, or an increase of 3380 B.t.u.'s, due to an increase in flue-gas temperature. If we assume, as before, that 30 per cent excess air is actually used, then the flue-gas loss at 2200 degrees Fahr. would be 12,000 B.t.u.'s, or an increase of 2380 B.t.u.'s due to excess air. This figure of 30 per cent excess air is

not high and there are a great many furnaces in operation where the excess air exceeds that amount.

Aside from the direct flue-gas loss, excess air manifests itself in other ways. Where excess air is used, the flame is sharp and cutting, and often causes a localized heat or blow-pipe action which forces the temperature of the refractories up to a point resulting in short life and increased maintenance.

Excess air also has a bad effect upon the material being heated. It produces scale on the carburizing boxes and shortens their life. If the material being heated is for drop-forging, the result of scale is shown in the shortened life of the dies. This evil of excess air is one of the most common, and there are few shops using industrial furnaces where the evil does not exist.

There are several ratio valves and mixers on the market which are intended to produce and maintain a constant ratio between the fuel and combustion air. The principles upon which these operate vary. One consists of a mechanical connection between the air and gas valve, so constructed that the two valves are operated simultaneously, and in the correct amount, to assure a properly proportioned mixture. To assure an intimate mixture of both fuel and air, they are passed through a small blower which forces the mixture to the furnace.

The other consists of a stream of high pressure gas which is forced through a venturi tube, and which draws in a sufficient volume of air for combustion. This apparatus is, within reason, automatic, as any increase in the flow of gas will cause a corresponding increase in the air. Devices of this nature are evidence that much attention is being paid to insure the proper combustive condition in the furnace with the resulting gain in fuel economy.

One other loss which can be seen nearly every day—is the tendency on the part of the operator to force the furnace when bringing up the heat. Forge furnaces are operated with great sheets of flame rising from the working opening; whereas, if the furnace had been operated with the chamber filled with flame, and only the amount of oil being used that could be entirely consumed within the chamber, the fuel consumption would have been reduced considerably.

It sometimes happens that the excess flame cannot be eliminated without sacrificing the furnace output. This is due to the burners not functioning properly. It was pointed out in the first part of this paper, that to produce high temeratures, it was necessary to burn large quantities of fuel in a small space, and to do this, a thorough mixture of the fuel and air was required. A poor mixture means long flames and long flames mean low temperatures, which in turn reduces output. The improvement in furnace operation—resulting from the use of proper burners, is due to the better mixture obtained, which reacts all along the line until the final result of increased output, or lower fuel consumption, is obtained.

While on the subject of forge furnaces, it should be mentioned that a great many in use today are too small for the work they are doing. It is poor economy to put in a small furnace and then force it to its limit for production. As a result of this practice excessive flue-gas temperatures occur together with their resulting high heat losses, excessive

refractory costs and a possible production loss due to furnace roofs failing without warning. The additional money spent for a furnace that can handle the job easily, will be returned many times in the form of lower fuel costs, increased production, and better heated stock.

Heat-treating furnaces with a plume of burning gas six inches high, rising from the vents, are no unusual occurrence. This is due to the desire of the operator to maintain a reducing atmosphere, and as an indicator, it is a sure thing, but it could have been reduced to a flame an inch long without sacrificing its efficiency as an indicator, or interfering with atmospheric conditions in the furnace.

In the average heat-treating furnace, operating at 1600 degrees Fahr. flue gases carry away nearly 30 per cent of the useful heat of the fuel. A great deal of this heat can be recovered by recuperation. With a temperature of 1600 degrees Fahr. in the chamber, a saving of 20 per cent in fuel has been shown, and as the temperature of the working chamber rises, the flue-gas losses increase and at 2400 degrees Fahr. 31.3 per cent of the heat of the fuel has been recovered and returned to the furnace.

Recuperation

The principle of recuperation consists of passing the hot flue gases after leaving the furnace over a pipe coil, or air chamber, containing the necessary air for combustion. In passing over the recuperator, as it is called, the waste gases give up their heat to the contained air which is used for combustion. This heated combustion air returns to the furnace the heat recovered from the flue-gas with the result that less fuel is required to maintain the desired temperature. The flame temperature with preheated air is also higher than when using cold combustion air, and this higher flame temperature increases the output of the furnace.

Conclusion

In summing up the foregoing it may be said that to insure low fuel consumption, a furnace should be operated with the least excess air possible and in the case of reducing atmospheres, no more fuel than that necessary to produce the desired conditions should be used. The burners should be of such design and operation as to insure an intimate mixture of the fuel and the air. Only that amount of fuel that can be completely burned within the furnace chamber should be allowed to pass the burners and the furnaces should be correctly proportioned for the work they are to perform. These conditions are direct and within the power of any operator to rectify. There are also other losses such as losses due to moisture in the fuel and to the moisture formed during combustion, as well as that which is in the air but which cannot be controlled by the operator. These points have been left out of the discussion.

The day is rapidly approaching when combustion in the forge shop and heat-treating room will be given the same consideration that it now receives in the boiler room.

A knowledge of the laws of combustion, and their application, as herein outlined will afford means whereby any furnace operator can show a substantial saving in fuel consumption.

TESTS SHOWING THE EFFECT OF HIGH TEMPERATURES IN MALLEABLE IRON

By T. D. Lynch and W. J. Merten

Abstract

This paper presents the result of numerous tests made upon malleable iron castings after they have been subjected to various high temperatures. The susceptibility of structural changes of malleable iron when subjected to various elevated temperatures is shown. The tests indicated a wide variation in critical temperatures of different samples of malleable which were tested.

The authors recommend the use of high annealing temperatures from 900 to 925 degrees Cent. (1652-1697 degrees Fahr.) for malleablizing when it is desired to obtain high quality of material with a high degree of ductility from annealing charges representng different chemical analyses. These tests also demonstrated the fact that it was possible to reheat malleable iron to the proper temperature without destroying its malleablized structure, however, too high a temperature will re-establish white, hard and brittle structure. Accelerated cooling appears to be conducive to finer grained ferrite and therefore a tougher and more ductile material.

MALLEABLE iron and its susceptibility to structural changes at various elevated temperatures has been investigated during recent months in connection with:

1st—Galvanizing, sherardizing and other surface protection processes where the maximum temperature does not exceed the visible red range, 480 degrees Cent.

2nd—Heating for the purpose of annealing mottled and white castings.

3rd—Heating for the purpose of straightening warped castings.

The changes occurring during galvanizing, sherardizing, and other surface protection processes have been described quite adequately by others and will not be discussed here.

In the heating for the purpose of annealing mottled and white castings, we approach the problem from the negative side. Here temperature is applied for the express purpose of changing the internal structures of the metals which are unfitted for commercial use.

Malleable iron consumers are frequently confronted with the fact that at the time of machining for assembling hard (white or mottled structure) castings are encountered and must either be reclaimed or delay production. An investigation was carried on to determine the advisability of malleablizing castings received in a hard and brittle condition, should the necessity demand such a procedure, instead of scrapping the castings and entering a replacement order.

A problem presented itself in the form of a malleable iron blower fan casting, Fig. 1, which was found to be so hard and brittle that a small deformation and light hammering caused it to break into fragments. Pieces of one of these castings were selected and the full hub part and one-half

---

A paper presented before a meeting of the society. The authors, T. D. Lynch and W. J. Merten are associated with the Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

of the rim were imbedded in iron scale (Fe_3O_4), and heated, in a gas fired furnace to a temperature of about 870 degrees Cent. for about ten hours, and then gradually cooled to about 700 degrees Cent. over a period of 30 hours, or a total period of 40 hours. The pieces were then taken from the furnace and cooled in air.

The rim part of the casting, Fig. 2, was bent through an angle of

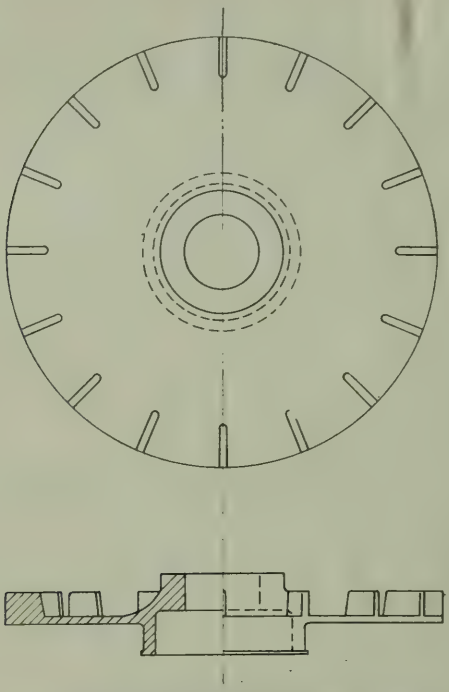


Fig. 1—Sketch Of Malleable Iron Blower Fan Casting Which Was Found To Be So Hard And Brittle That A Small Deformation And Light Hammering Caused It To Break Into Fragments.

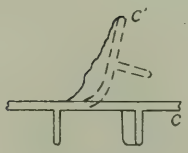


Fig. 2

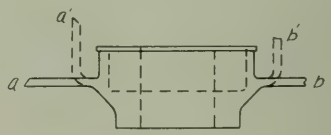


Fig. 3

Fig. 2—Sketch of Rim Part Of Casting Which After Annealing Was Bent Through An Angle of 75 Degrees Before Breaking. The Fractured Section Showed A Good Black-Heart Structure. Fig. 3—Sketch Of Hub Section Of Casting Which After Annealing As Described In Text (a) and (b) Bent Through An Angle Of 90 Degrees Without Breaking Or Showing Any Sign Of A Crack Or Rupture.

approximately 75 degrees before breaking and the fractured section showed a good "black-heart" malleable structure. On the hub section of the casting,

Fig. 3, parts (a) and (b) were bent through an angle of approximately 90 degrees without breaking or showing any sign of a crack or rupture. This test demonstrated the fact that hard and mottled iron can be reclaimed by a single heating process.

A second problem of reclaiming motor bearing housings and commutator end plates brought out some new ideas relative to annealing temperatures.

The annealing or malleablizing temperature range of malleable iron is usually given as 700 to 750 degrees Cent. for air-furnace iron and 800 to 900 degrees Cent. for cupola iron. Our experiments however, indicated that this temperature was much too low for consistent results on air-furnace iron. To assure attainment of correct annealing temperatures of a charge

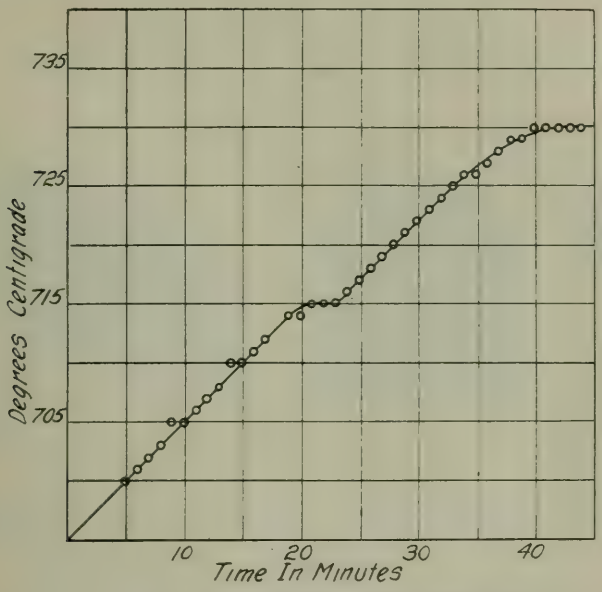


Fig. 4—Heating Curve Taken During Experimental Treatments In Reclaiming Motor Bearing Housings.

of motor bearing housings, the fire end of a thermocouple was placed in a hole, drilled in the side of the casting.

The heating curve of Fig. 4, was taken and the temperature for the starting point of the annealing cycle raised to 730 degrees Cent. or slightly above the critical point 715 degrees Cent. of the casting under observation. This is illustrated by the bends of the curve.

The fracture tests of this casting are shown in Figs. 5 and 6; the original white fracture in Fig. 5, and the malleablized "black-heart" structure in Fig. 6.

On the other hand a commutator end plate constituting a part of the same charge broke sharply with the full white fracture, shown in Fig. 7, indicating that the critical temperature of this iron had not been reached during the annealing operation. The heating curve of Fig. 8 subsequently obtained, proved the correctness of this assumption.

The end plate was then annealed above its critical temperature as shown in Fig. 9, resulting in an excellent malleable structure of Fig. 10. Photomicro-

graphs, Figs. 11 and 12, further illustrate this change of microstructure accomplished by a relatively high annealing temperature. Photomicrograph, Fig. 11, taken before the second annealing shows a perfectly white structure consisting of cementite plus cementite eutectic while photomicrograph, Fig. 12, taken after last annealing, shows a thoroughly malleablized structure of a "black-heart" casting, consisting of a ferrite plus free graphite.

The analyses of the two irons are as follows:

	Combined Carbon Per cent	Graphitic Carbon Per cent	Mang. Per cent	Phos. Per cent	Sulphur Per cent	Silicon Per cent
Motor Housing	0.01	2.00	0.28	0.16	0.068	0.75
End Plate	0.05	1.97	0.24	0.20	0.13	0.83

The difference in analysis is relatively small in all constituents except sulphur and to a less degree in phosphorus. Since air-furnace iron was used

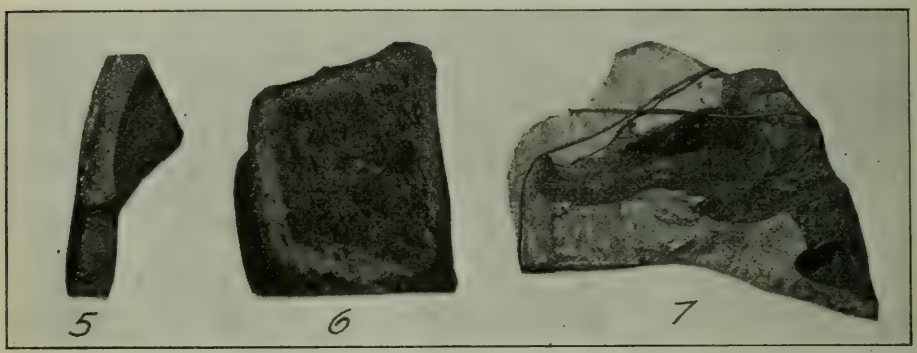


Fig. 5—Shows The Original White Fracture Of Motor Bearing Housings And Commutator End Plates. Fig. 6—Shows A Malleablized "Black-Heart" Structure Of One Of These Parts. Fig. 7—Shows A White Fracture On One Of The Commutator End Plates Which Was Treated In The Same Charge As The Others. This Indicates That The Critical Temperature Of This Iron Had Not Been Reached During The Annealing Operation.

for both castings, it seems reasonable to conclude that the presence of higher sulphur and phosphorus requires a higher annealing temperature than when these limits are relatively low.

A third problem of straightening blower fan castings in a press while heated to a red heat led to a further investigation to determine the temperature to which a malleable iron casting of thin section (3/8-inch maximum) may be heated and held for a reasonable length of time before the graphitic carbon is redissolved or changed back to the cementite (Fe_3C) or combined form, producing a brittle white casting.

A number of malleable iron castings of thin section which were straightened by being heated to a cherry red or perhaps hotter and pressed in a die were returned after this operation in a brittle white condition. They had been soft and malleable previous to the heating. The casting which had been broken was selected for test and was a fairly good malleablized material. It exhibited a "black-heart" malleable grain structure. The casting was heated fairly rapidly in a gas-fired furnace to 730 degrees Cent. and held at this temperature for one-half hour. It was then placed on a cold steel slab and cooled to a black heat of somewhere near 375 degrees Cent. in air, and finally quenched in cold water. The cold casting was then

broken under a hammer at section (a) Fig. 13. The casting bent through an 80 degree angle before breaking and the fracture was sooty, as that of the original casting.

The remaining part of the casting was replaced in the furnace and heated to 815 degrees Cent. and held at this temperature for one-half hour, when it was withdrawn and cooled as above. The casting was broken at (b) Fig. 13 after having been bent through an angle of almost 80 degrees with a fracture of even better grain structure than either the original casting or the

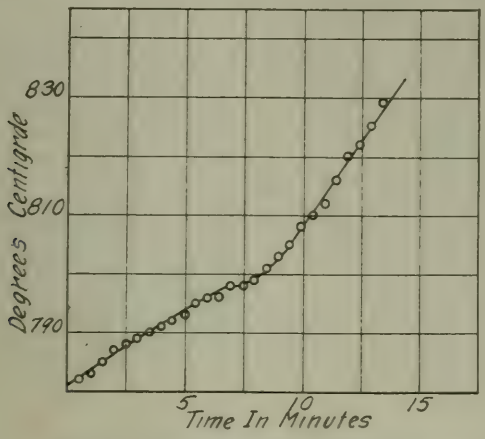


Fig. 8—Heating Curve Taken During Experimental Treatments In Reclaiming Commutator End Plates.

one broken after the 730 degrees Cent. treatment. The remainder of the casting was again put into the furnace and heated to 925 degrees Cent. and held again for one-half hour, and cooled again as above.

After this treatment the fracture as shown at (c) Fig. 13 was sharp and white indicating very brittle iron.

Table I

Effect of Temperature in Malleablizing Iron

	Degrees Centigrade					
	Heated to	Held in furnace	Cooled on cold steel slab	Quenched in cold water	Angle of bend	Grain structure of fracture
Original	...	.....	...	..	70	Black heart malleable
Section A.....	730	½ hr.	375	20	80	Black heart malleable
Section B.....	815	½ hr.	375	20	80	Black heart malleable
Section C.....	925	½ hr.	375	20	Sharp break	White

Examination revealed the fact that the carbon had been redissolved and combined with the iron to form Fe_3C (Cementite).

Results are presented in tabulated form in Table I.

Summary

These tests indicate a wide variation in critical temperatures of different samples of malleable iron, from 715 to 800 degrees Cent. as shown on Fig. 4, even though the range of chemical composition is such as is often found in malleable iron. It also indicates a decided influence of sulphur and phosphorus upon the position of the transformation points.

The employment therefore, of high temperature annealing from 900 to 925 degrees Cent. for malleablizing, is advocated when it is desired to obtain

high quality material with a high degree of ductility from annealing charges representing different chemical analyses.

It may also be inferred that the well known practice of employing higher annealing temperatures for cupola than for air-furnace malleable iron

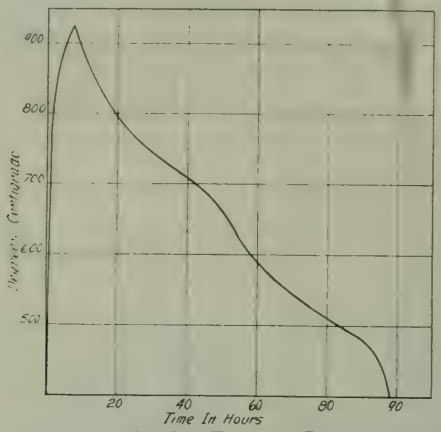


Fig. 9—Electric Furnace Record Taken During The Malleablizing Treatment Of Commutator End Plates, Resulting In Excellent Malleablized Structures.

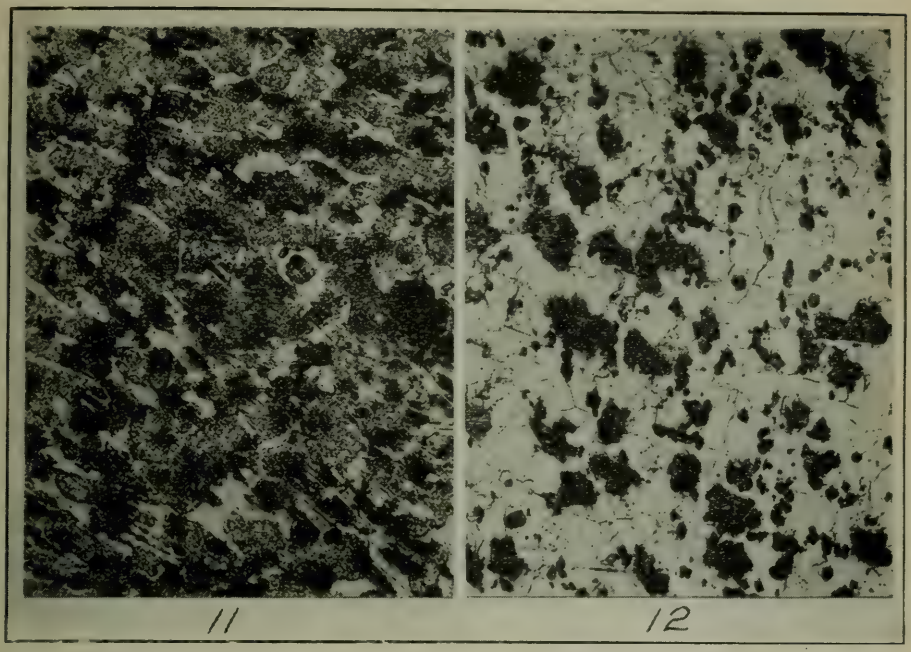
Fig. 10—Fractured Malleablized Casting Showing An Excellent Malleable Structure Resulting From The Annealing Treatment As Shown In Fig. 9.

is due primarily to the higher sulphur and phosphorus content in the charge, rather than purely to the different methods of manufacture. The difference of chemical composition in sulphur and phosphorus does not seem to affect the quality of the product, provided proper temperatures are employed in annealing.

These tests also demonstrated the fact that it is possible to reheat malleable iron to a proper temperature for straightening without destroying its malleablized structure, but that too high a temperature (925 degrees Cent.) will re-establish the white, hard and brittle structure.

It is therefore safe to conclude that:

1. The straightening of malleable iron castings may be safely done without causing the whitening or embrittling of the casting by heating them to a dark cherry red and then subjecting them to the straightening operation in a forge press, provided the time of holding the casting in the furnace is relatively



Figs. 11 and 12—Photomicrographs Which Illustrate The Change Of Microscopic Structure Accomplished By A Relatively High Annealing Temperature. Fig. 11—Taken Before The Second Annealing Shows A Perfectly White Fracture Structure. Fig. 12—Taken After The Last Annealing Shows A Thoroughly Malleablized Structure Of A Black-Heart Casting. x 100. Specimen In Fig. 11 Was Heated To 730 Degrees Cent. (1346 Degrees Fahr.) Specimen In Fig. 12 Was Heated To 925 Degrees Cent. (1700 Degrees Fahr.)

short and does not constitute a soaking operation of several hours.

2. The method or time of cooling does not seem to lessen the ductility of the castings so long as the carbon component is in the amorphous

Fig. 13—Sketch Of Blower Fan Casting Showing The Type Of Fracture Which Resulted From The Several Treatments Given This Casting As Described In Text.

or graphitic condition. On the contrary, an accelerated cooling is conducive to finer grained ferrite and therefore a tougher and more ductile material.

The reaction of cementation on heating to a high temperature (925 degrees Cent.) is reversible. Therefore, an exceedingly slow cooling after combining the carbon, results in breaking up the cementite into iron (ferrite) and graphitic carbon.

Conclusions

Hard castings are objectionable for two reasons, they are brittle and they destroy tools when machining. In order to eliminate the occasional hard casting from a shipment of malleable iron, it is advocated that a higher annealing temperature above the critical range of all castings, be used in order to malleablize such castings as happen to be high in phosphorus and sulphur. Warped castings may be straightened at temperatures below the critical range without damage. White castings may be properly malleablized in an ordinary open fired gas annealing furnace by correct processes.

Discussion of Paper

Chairman French: Mr. Lynch's very important paper is now before you for discussion.

Mr. Norris: I would like to ask Mr. Lynch if he tried restoring the castings by heating to a lower temperature than the critical point without packing the outside, and if so, what results he had.

Mr. Lynch: Yes, we tried to bring them up to a point below the critical range but found no change in structure up to the critical range. In other words, we heated them up to a point below the critical range for straightening purposes without changing the structure and above the critical range in the presence of oxides to refine and soften.

Mr. Merten: I might add to Mr. Lynch's remarks that we were interested in keeping down the oxidation as much as possible because we didn't want any undue reduction in section, however, we were interested in having the benefit of the decarburized, tough skin in a malleable iron casting since this increases the ductility.

Mr. Loudenbeck: I would like to ask Mr. Lynch what effect the preheating has on the carbon.

Mr. Lynch: Mr. Chairman, we didn't make an analysis of the combined carbon except as was suggested from the fractures. There was no change made that we could observe up to the critical point. When it went above that point we did get a change, making the casting brittle. If they were heated up in the presence of iron oxide we were able to remalleablize the castings.

Mr. Merten: Mr. Loudenbeck, you refer to the reduction of total carbon. Photomicrographs are given in the paper itself and they do show the eutectic ferrite-cementite condition in the light casting, with the sooty, annealed condition in the other. Mr. Lynch has the photographs in the paper. I suppose there is a reduction in carbon, due to the decarburization of the surface, it is hardly possible to heat the casting as high as we did and not decarburize it.

Mr. Loudenbeck: My experience has been that a slight change occurs in preheating. There was practically no combined carbon in the annealed condition.

Mr. Lynch: We found no deleterious results from that.

Mr. Merten: The paper gives results of such tests and it shows that the ductility of the casting actually increased on heating. We had a better fracture after the heating up to about 700 or 800 degrees Cent. and cooled and the bending tests showed up very much better.

FORGING PRACTICE FOR AUTOMOBILE PARTS

By R. T. Herdegen

Abstract

The author of this paper has presented a general and practical discussion of the many items which are involved in the production of drop forgings for automobiles. He discusses the various types of machines which are used in the production of drop forgings both in the eastern and western shops.

The main items or factors which go to make up the total cost of manufacturing drop forgings is reviewed in a general way.

The design of the die and the type of machine used bear a very important relationship to the ultimate cost and it requires close study and co-operation both on the part of the producer and consumer to obtain the minimum cost per unit. Close metallurgical control of the raw material is imperative to uniform quality production.

THE title of this paper should perhaps be "How Automobile Parts Have Developed the Forging Business" rather than "Forging Practice for Automobile Parts," for the reason that the drop forge business was a tender infant until the advent of the automobile. Previous to that time, drop forge work was largely restricted to the making of various tools such as wrenches, pliers, screw drivers and to the fabrication of carriage hardware. The shops making these parts were practically all located in New England and the combined output of the forging shops west of Pittsburgh was probably not equal to the output of one of the larger eastern shops.

Types of Machines Available

There are various machines available for the purpose of making drop forgings. Each machine has its own special good points and its own inherent disadvantages. It cannot be said that there is one particular type of machine which is most suitable for all types of forging work. The type of machine used for making the great bulk of forgings is the drop-hammer. The two main classes of this unit are the steam-hammer and the board-hammer. There has been a great deal of controversy as to the relative merits of these two types of machines ever since the great expansion in the drop forge business started.

Board-Hammers Used Largely in Eastern Plants

Eastern shops were largely board-hammer shops with here and there a stray steam-hammer. With the coming of the automobile, the manufacture of which is practically entirely in the west, there came the development of the huge western shops with which we are all familiar. These shops were equipped practically entirely with steam-hammers.

The result of this development was that eastern drop forge men considered board-hammers the proper type of equipment for forging

A paper presented before the Detroit chapter of the society. The author, R. T. Herdegen, is vice president and general manager of the Dominion Forge & Stamping Co., Walkerville, Ont.

while the western drop forge men considered steam-hammers the proper equipment. This heated argument continued for several years with the usual result that neither side convinced the other side. Then came the World War with its upheaval in labor conditions, which meant high-priced coal with resultant greater operating expenses for steam-hammers. The gap between the original costs of the two classes of hammers also widened tremendously, which meant greater relative depreciation, interest charges and up keep. At this time in the argument everybody began to seriously consider both types of equipment and began to realize that it was not a case of one type of equipment versus another but a case of getting the proper machine for each specific job.

Headers and Bull-Dozers Used

There are several other types of equipment used in making forgings in addition to hammers, the most important of which is the upsetting machine or so called, header. There is still another type of machine which in its general action resembles the upsetter, namely, the bull-dozer in the restricted sense of that term.

In addition to these units, there are various minor units such as Bradley hammers, special types of air hammers and rolls. These latter units are however restricted in their uses and are usually required in conjunction with the main units of forging practice to perform auxiliary operations. Hydraulic presses are also used for very heavy work of a special character, which would otherwise be made under large open frame hammers, rather than by double frame forging hammers. The main units that will be considered in this paper will be board-hammers, steam-hammers and upsetters.

Determining Costs

Selection of Proper Machine for Efficient Forging

In the early days of the drop forge business the question of the proper machine for a given job was decided solely on the basis of costs. The machine which would do the cheapest job was considered the proper machine for that job. Unfortunately this is still true of a good many shops today.

Three Principal Items Involved in Figuring Costs

Material Costs

In considering the problem from this angle there are three items to consider; the material used, the labor required, and the overhead involved. In general, upsetters use less material in making a job than any other type of forging apparatus. Most typical upsetting jobs are of such a character that there is no loss due to the flash. In other words, trimming is not necessary, the forging comes completed from the unit ready to machine. There is, however, a certain item of lost steel to be considered, namely, the short end of every bar used in upsetting work. The operator starts making forgings from a long bar but soon arrives at a point where the bar is so short that it cannot be used to make forgings. In many cases this short end can be used to good advantage on another job of the same analysis steel or sometimes it even pays to make up a hammer-die to use up these short ends for the

same job as is being made in the upsetter. A short end, however, must always be taken into consideration and sometimes on jobs using a large diameter bar such as a six-inch bar, the expense of putting this large diameter short end to an economic use, will eat up the material saving effected on the first pieces made from the bar.

Labor Costs

In general, the labor costs of making a forging should be more or less the same whether it is made in one type of apparatus or another. In speaking of labor, productive labor only is considered and in the case of the average forging the productive labor is rarely more than 15 per cent of the total cost. Of course, if one type of apparatus will make a great many more forgings in a day than another type of apparatus the labor cost on the first unit will be considerably less per piece: inasmuch as the total daily earnings of an operator should be about the same regardless of which unit is used. Occasionally more men are required to handle the job when made in one type of apparatus than in another, which of course will also increase the labor cost per forging in the case of the former. However, increased production per hour may result which may more than overcome the labor increase.

Overhead Costs

The overhead charge is by far the most important factor in drop forge costs. For most forgings the overhead cost is as much as the material and productive labor cost added together unless the material used is high-priced steel. In the case of the average carbon steel forging, the material and labor charges combined are always less than the overhead charge. In considering the matter of overhead, we should compute this only on the machine-hour basis. In other words, for every piece of apparatus or production center the cost per hour of operation should be determined. This may run all the way from a few dollars an hour to a charge of fifty dollars an hour or even higher. The overhead cost is then manifestly equal to the overhead charge per hour for the production center divided by the piece production per hour. For example, we might consider a unit which costs twenty dollars an hour to run, making ten axles per hour. Estimating on this forging, the overhead cost per axle would be two dollars. The overhead cost then per forging is entirely determined by the production per hour possible on the unit. This does not necessarily mean that it is always best to put a forging on the machine that will produce the greatest number of pieces per hour, because th oveerhead charge per hour on this unit may be so great that the charge per forging is greater than that obtained from a smaller unit making a smaller number of forgings per hour and which, nevertheless, produces a lower cost per forging.

This discussion relative to the merits of the different types of apparatus has been based entirely upon the question of costs of production. The last few years, however, there has been a great advancement in the investigation of the effects of working steel on the ultimate forging purchased. In this connection the question of grain size and arrangement has developed to be of considerable importance, particularly

in the case of gears. It is possible to obtain a grain arrangement in the finished forgings on an upsetter which is usually impossible in a hammer. This is particularly true in the case of gears with a large diameter. In the case of gears with a small diameter, the desired grain arrangement can be obtained by cutting the steel into the proper sized small cylinders and then forging them on end. This process however, is liable to be more expensive than the upsetting process.

It has also been discovered that it is possible to obtain a forging too quickly. The effect of several smashing blows on a piece of steel is such that the ultimate product will not always be as satisfactory as when it is made with a larger number of less vigorous blows. This may mean, however, that fewer forgings per hour can be produced by the latter method which in turn means a higher cost per forging.

The cry of the purchasing agent for the last two years has been entirely on the question of price. Fortunately, however, in a few instances lately the result of the investigations of some of the members of this society has indicated that on certain forgings it was very desirable to obtain a certain grain arrangement or to take more blows or more upset operations on a certain forging. The writer is not a metallurgist but appreciates the fact that the number of blows or upsets required to make a given piece will in many cases materially affect the ultimate wearing qualities of the finished forging. The time does not appear to be very far distant when the purchasing agent in asking for quotations on a certain special forging, will state definitely the number of blows or operations which the purchaser desires to be used in the manufacture of that forging. It is absolutely necessary, however, to convert the purchasing agent to the idea that there is something to forgings besides the price per piece. As long as forging purchasing is done entirely on this basis the man who makes the greatest number of pieces in the shortest possible time will get the order, even though his product is not as desirable as the product which is more painstakingly made but which costs more money.

Die Design An Important Factor

Intimately connected with the question of the number of operations in making a forging, is the question of die design. In the discussion on the number of blows required to make a forging it was assumed that the die was exactly the same whether two or four blows were used on the hammer. It was merely a case of using a lighter hammer with the same type of die. In the forging of many pieces, however, it is possible to regulate the speed at which the metal is obliged to flow by varying the design of the die. The number of operations made on an upsetter is determined practically entirely by the die design which determines the amount of stock to be gathered in any one operation.

The average forging is made in two impressions, the rough and the finished and usually with a break down placed on the side of the die as a preliminary operation. If it is desirable to work the steel slowly, more impressions must be used, but there is a limit to the number of impressions that can be put into one die-block. This means that it is often necessary to have two sets of dies running in two separate hammers. The first set of dies is usually referred to as blocking dies and the second set as the finishing dies. There will prob-

ably be at least two impressions in each of the dies besides the break down in the blocking dies which would mean five steps in the making of the forging.

The Determination of the Proper Number of Impressions is Imperative

Most of the motor car companies have had considerable trouble with connecting rods and it is probable that a great deal of trouble has been due to trying to make a perfect rod with too few impressions. The competition in connecting rods has been probably the keenest competition in the drop forge business. It has been a case of an effort on the part of the manufacturer to make the maximum number of rods per day with the use of the smallest number of pieces of equipment. It is no incentive to a drop forge concern to block connecting rods in one hammer and finish them in another unless the company receives more money for this extra work. A certain well known motor car company recently ordered a quantity of rods specifying that they were to be first blocked and then finished and the die design was to be approved by their metallurgical department. This is certainly a step in the correct direction.

The writer does not wish to indicate from these remarks that it is desirable for every forging to be made as slowly as possible with as many operations as possible. It certainly is true, however, that in the case of a critical part on a motor car where breakage might cause serious damage or perhaps loss of life, that motor car companies should take advantage of the investigations of the "metallurgical department" and purchase forgings not alone on price. They should also consider the manner in which this forging is to be made.

Quality of Steel Used is Paramount

When a drop forge company receives a shipment of steel it should assure itself that the analysis of that steel is correct. If it is not correct it should never work that material into finished product. In addition to the question of analysis there is the very important question of seams. It sometimes happens that surface seams will disappear in the flash in making the forging but this is rare and should not be considered as an excuse to use seamy stock. The forge companies are much better off to refuse absolutely to use seamy stock, certainly in the case of stock which is to be used in connection with upsetters. Stock, which may show only slight surface seams, when worked in an upsetter will open up on flanges in a most surprising fashion and make a forging which is so defective that the average forger will never consider even shipping it from his plant.

This brings up again the old question of forging-quality bars. On the one hand there is the steel company advising the forge man to buy nothing but forging-quality steel, while on the other hand, there is the customer buying the forging as cheaply as possible. A drop forge concern may bid on a certain forging with every intention of using forging-quality bars which means paying the extra charge by the steel company. Before the negotiations are completed he is advised by the purchasing agent that his price is high. He immediately decides to use ordinary forge bars and thus make it possible to quote a lower price.

It is probably true that for many forgings which are not put to any severe strain or which are not particularly difficult to forge, that ordinary bars will be satisfactory, but in the case of certain critical forgings or forgings which require an unusual amount of working, it is desirable to purchase forging-quality steel. As mentioned above upsetting will bring out any defects in a steel bar so that it is usually suicidal to purchase ordinary steel for upset operations.

Steel Frequently Furnished by Customer

A large number of motor car companies make it a practice to purchase the steel for the drop forge man. This is certainly an advantage from two points of view. It enables the motor car company to be sure that the proper steel is used in making their forgings and also ensures uniformity of the product as far as steel is concerned. The drop forge man is also benefited by this procedure because he knows that his competitor will naturally plan on using the same character steel which is sold to all bidders for the same price. If there is any difficulty with the steel the entire problem can be referred to the motor car company which in many instances is able to accomplish more with the steel company than the average forge concern. Also the larger motor car companies are able to maintain an adequate metallurgical department which can investigate the steel problem much more thoroughly than such a department operated by a drop forge concern. The bulk of the drop forge companies are not in a position to be able to maintain the extensive metallurgical departments required to properly check steel purchases; so that it would appear in the final analysis that the method of having the motor car company purchase and be responsible for the steel, is the best method of handling the steel question.

Conclusion

Summing up these brief remarks with reference to forging practices for automobile parts, it would appear that the forging business owes its present great development entirely to the motor car industry and that the direction in which forging practices in the future tend will depend almost entirely upon the interest that this group takes in the forging business. If the American Society for Steel Treating members can convince their respective companies that it does make a difference as to the character of the steel used for forgings and as to the method in which these forgings are made, then the drop forge business in the future will improve and the class of work turned out will be superior to a great deal of that made today. If on the other hand, the motor car companies are interested only in the price of forgings they will merely get a forging which has the correct dimensions but whose internal structure may be very far from that which is desirable for the work to which that forging will be subjected. As a drop forge man the writer hopes that the former alternative will prevail and that the question of quality in drop forgings will receive greater attention in the future than it has in the past.

Discussion of Mr. Herdegen's Paper

Chairman J. L. McCloud expressed the chapter's appreciation to Mr. Herdegen for his interesting presentation and announced that the

speaker would be very glad to answer questions and discuss points in reference to the drop forging of automobile parts.

Mr. Danse: I would like to ask Mr. Herdegen, in regard to the forging of axle sections, whether he considers it better to fuller it and edge it before finish forging, or whether he considers it better to fuller it and edge it and be sure the fullering and edging brings the section down so that it will just fill the impression in the die before finishing.

Mr. Herdegen: I would say that there have been a good many experiments conducted in the forging of axles by different companies, and as the axles are not all the same, what may be very good practice for forging one axle may be very bad for forging another. In general, I would say that it is better to make the steel flow in such a manner that you do not have a cross grain, and it would depend upon the design of axle and size of stock as to which method you would use.

Mr. Danse: You would say, then, that if the axle had very deep flanges on the I-beams it would be better to have two impressions, and if the flanges are not so deep it would be just as good to block it out.

Mr. Herdegen: That would be my idea, yes.

Mr. McCloud: As Mr. Herdegen said, as large a part of the problem as anything is in die design.

Mr. Herdegen: I might make the remark that the drop forge business in the last few years is practically entirely a question of price. That is, you can make any forging you want, to any dimension you want, providing you receive sufficient money to justify that work. During the war we made forgings and they were forged in such a manner that they would not have to be machined. We got them to .001 inch. That meant cold restriking and a lot of other operations. They cost about 25 or 30 cents per pound. They were very expensive, but the people who purchased them felt that they saved enough money in their machining to justify that price. The same thing applies to forgings coming up every day. You do not like a forging if it looks this way or that way, but the forge men can do most anything that you gentlemen want them to do. It is up to you gentlemen to convince your purchasing department that it is worth the extra money that it costs to get the forging the way you want it.

Mr. Blasko: Have you had any experience in forging or rather rolling gears to a size so close that they will go in the car without machining?

Mr. Herdegen: No, I have never had any personal experience with those. I have seen them being made, however. A concern in Cleveland, rolled about 500,000 the same as used for Ford cars. So far as I know they are all running.

Mr. Blasko: Do you know how the price compares?

Mr. Herdegen: Yes, these gears sold a good deal cheaper, but it was hardly a fair comparison, because they were made out of carbon steel, whereas Mr. Ford makes his out of alloy. While the difference of average comparison is not as great as you would figure it might be, still I think it worked out about 15 cents on that gear.

Mr. Blasko: Did they also make some worms?

Mr. Herdegen: Yes, they also rolled some worms. I didn't go into that. The machines are very expensive and the dies are very ex-

pensive, and they don't last long. After you run about three or four hundred you have to take the dies out and regrind them.

Mr. Blasko: Do they roll it in one heat?

Mr. Herdegen: Yes, it is a quick job, but hard on your machinery.

Mr. McCloud: We had some experience out in Dearborn with some forged gears,—differential gears and differential pinions, that were pretty well forged to size. However, they were not sufficiently close to size but what they had to be machined, the teeth generated, beside other machining operations, and after running them for a little while in the machine shop and all the way through the plant we found that the actual cost was as great if not a little bit more in the case of the gears that were forged; that is, the extra cost of the forging was a little bit more than the cost of cutting the teeth. In other words, it didn't cost us any more to take a roughing cut on the gears than it did to forge them. Possibly that was mostly owing to the life of the dies. The cost of forging the teeth in, was of course, dependent on the life of the dies, and to get sufficiently close to maintain the limits for roughing, the dies cost too much.

We have been quite successful in the use of a worm which was partially rolled to size. Of course, more material was taken off so that there was a distinct saving in the case of the worm, but not in the case of the gears.

Question: What makes up the overhead cost and what is the largest item in this cost?

Mr. Herdegen: What part of the machine are you interested in?

Question: On an axle for instance, a $50.00 an hour machine.

Mr. Herdegen: Yes, that would be a large machine. The biggest item would be on the upkeep of the machine itself.

Mr. Herdegen: Well, we have a machine that gives an answer of $39.00. That is the largest one we have, so I will give you its analysis. In figuring overhead the only units in your shop that could earn you any overhead are your actual production units. In other words, the boiler room, electrical department and other non-productive departments are all charged up against the hammer shop so it must stand the whole burden. In figuring this charge we take the hours that each unit operates and multiply those hours by the rate in each case. If your shop is running 70 per cent you will earn all your overhead very nicely, but unfortunately the last two years they have not been running 70 per cent.

Referring to the total charge of $39.00 per hour which is the machine rate on an eight thousand steam hammer, it may interest you to know that the same is divided up about as follows:

All handling charges of material covering unloading, shearing, trucking and grinding as well as inspection in the shop and shipping room, produce a total of $4.50. The total coal charge including the boiler room labor and overhead amounts to $4.00. Furnace oil, the cost of producing furnace air and the repairs on the furnaces increase the overhead $7.00 per hour. Maintenance of machinery and equipment including the repair parts purchased and the labor involved in their machining and installation total $6.000. Shop charges for superintendence, insurance, taxes and depreciation are $5.00 more. Administration, commercial expense and sales expense total $4.50. The complete cost of dies which

covers material, labor and overhead involved in their production mean a charge of $8.00. The sum total as you will note, is $39.00.

Question: Isn't it general practice to have the customer stand the die charge

Mr. Herdegen: Yes, but the average forge company doesn't get enough out of dies to buy stamps. The charge made by the average company never pay for making these dies.

Mr. Learmouth: Mr. Herdegen, along that same line I have some figures here. We check our cost per thousand pounds of forgings produced. With our way of estimating our die and tool cost, that is; everything connected with the cost, amounts to $3.84 per thousand pounds of forgings produced and the die upkeep runs about $3.24. In other words it costs as much to repair the dies as they originally cost. Then our hammer repair, which is the labor and repair parts for the upkeep of the hammers runs about $2.50 per thousand pounds. Our furnace, which includes brick, labor, fireclay and oil, runs about $1.80 per thousand pounds of forgings produced.

Mr. Herdegen: What is your total per thousand pounds of forgings produced?

Mr. Learmouth: $11.38. Of course, that is just for those four items. We have other accounts but I cannot recall just what they are.

Mr. Herdegen: Of course, that would really vary depending on the size units used?

Mr. Learmouth: Well, that is taking an average. Of course, if we were a contract shop we perhaps would not estimate that way.

Mr. Herdegen: Of course, being your own consumer you don't have to worry about that.

Mr. Learmouth: That is just the point, we do. When our purchasing department comes along and says "We can buy that forging cheaper than you can make it," that puts us in hot water.

Mr. Atkinson: Is that cost $39.00 per ton?

Mr. Herdegen: No that is the cost per hour of running that particular machine. If that machine turns out only 39 forgings in that hour there is $1.00 overhead on each forging. On a certain hammer you may at one time have only one man working, and another time you may have half a dozen or more. The cost of operating the hammer is the same regardless of whether you have one, two, three or four or more men running it. That is why the forge men do so much to try to make the die produce the maximum number of forgings per hour.

Mr. Atkinson: I think that these points Mr. Herdegen brings out in connection with the cost of operations in the forge shop are some that everyone of us should keep in mind in connection with the operation of our heat treating departments. We hope a little bit later in the season to have a meeting in which heat treating costs will be discussed. The points brought up in regard to die costs may give us some idea of the line along which we should work in computing costs in our heat treating departments.

Mr. Blasko: In that case you mentioned, would that hammer produce a ton of forgings?

Mr. Herdegen: That would depend entirely on the particular design of forging put in that hammer you see. That hammer is going to use a certain amount of steam regardless of whether you turn out

one ton or two tons. It may be a forging that is complicated to make, and it may only turn out as few as ten an hour, and then it may be a simple one and you may get forty an hour. You can imagine making a large flat gear, you would turn out a large number, and the next time put in a complicated truck axle, and you turn out less.

Mr. Blasko: Do you charge in accordance with that?

Mr. Herdegen: Yes, sir.

Mr. Blasko: Some of them are quite high.

Mr. Herdegen: Yes, they are. Did any of you gentlemen see those complicated forgings at the American Society of Steel Treaters exhibition. Did you notice that gun carriage forging. I think it cost around $250. It was very complicated, had to be made in a very large hammer, and they only produced about thirty or forty a day.

Mr. Blasko: How large was it?

Mr. Herdegen: The net weight I think would be around 250 pounds. It cost over 10 cents per pound.

Mr. McCloud: It is just a question of analysis of cost. That is why this talk Mr. Atkinson referred to is going to be so interesting. I think too few of us in the heat treating work realize the necessity of cost analysis, and most of us are ignorant of the methods of attack.

Question: I would like to ask whether the steel companies have any right to expect the forging company to stand any loss?

Mr. Herdegen: I would like to know why, when we pay that extremely high price so as not to have any liability, why we should assume it. I would carefully lay all the defective pieces out and ask them to come over and see them.

Mr. Learmouth: I check on that because it seems to be the custom of the steel companies to try to educate the forging companies. We have a small amount of loss, 2 per cent loss and if that, while it is small, were added to a, say, 3 per cent loss in steel, it would be more than I believe we should stand. We have to stand our amount of loss in the forge shop, and I think it no more than right that they stand their own.

Mr. White: For material made in the same size ingot do you notice any difference between the electric furnace and the open hearth?

Mr. Herdegen: That I would have to refer to the metallurgical department, Mr. White, as I do not know.

POURING TEMPERATURES OF STEEL CASTINGS

By H. K. Briggs

Abstract

This paper, dealing with pouring temperatures of steel castings, indicates that the foundryman seldom pays much attention to the pouring temperature of the steel he is turning into his molds.

The author of this paper has demonstrated the effect of varying pouring temperatures on the physical characteristics and properties of castings poured into similar molds under uniform conditions using the same heat of steel for these tests, keeping all factors excepting the temperature of the molten steel constant.

The rate of cooling the steel from the molten to the solid state has considerable effect upon the resulting microstructure of the casting. With a Widmanstatten structure caused by slow cooling from an elevated temperature, weak castings result, which can only be improved by a suitable heat treatment. Photomicrographs and physical test results accompany this paper.

Introduction

IN ALL of the work on the heat treatment and working of steel, but little mention is made of the effect of the temperature at which the original ingot or casting was poured into the mold. If variations in the pouring temperature affect the structure and properties of the product in such a way as to render it an inferior article capable of being improved to the desired quality, then it is a very proper consideration for a body of men engaged in the treatment of steel.

The aim of this paper is to show the effect of varying the temperatures at which steel castings of the same composition are poured. Five castings of the same heat were poured into molds of the same dimensions all air dried for three days, made from the same sand at the same time, thus eliminating all variables as far as possible. The castings were poured at temperatures varying from that at which the steel would just run, to that at which it smoked excessively and cut the sand to a marked extent. They were cooled over night in the mold. The usual physical tests and photomicrographs are herein presented to show the varying effects of this treatment.

Pouring of Castings

The castings were cast in blocks 4 x 8 inches in section with three lugs running the length of the bottom side, ⅞-inch round by 11 inches long. A 4-inch riser gave a total head of 12 inches. These lugs were nicked and knocked from the block, and turned to A. S. T. M. standard 2-inch gage length, threaded end test bars.

Chemical Analysis

The following is the chemical analysis of the heat:

	Per Cent
Carbon	0.27
Manganese	0.48
Silicon	0.23
Phosphorus	0.033
Sulphur	0.048

A paper by H. Kenneth Briggs, metallurgist with the Minneapolis Electric Steel Castings Co., Minneapolis, Minn.

Pouring Temperatures

The blocks were poured at the following temperatures:

Series	Temperatures by Pyrometers Degrees Cent.	Degrees Fahr.	Observations
1	1470	2678	Solidification set in across top of ladle
2	1485	2699	Slight solification as in No. 1
3	1500	2732	Metal smoking very slightly
4	1525	2771	Metal smoking excessively
5	1650	2822	Metal smoking more than in No. 4 and in turbulent condition

Physical Properties

With the exception of block 5, two tensile test specimens were machined from each block and were pulled on a tensile testing machine. Block 5 was filled with large blowholes, showing that the excessive heat used in casting had been such as to render the steel wild and the blocks unsuitable for test. Table I shows the physical properties of the bars tested.

Table I
Tensile Test Results

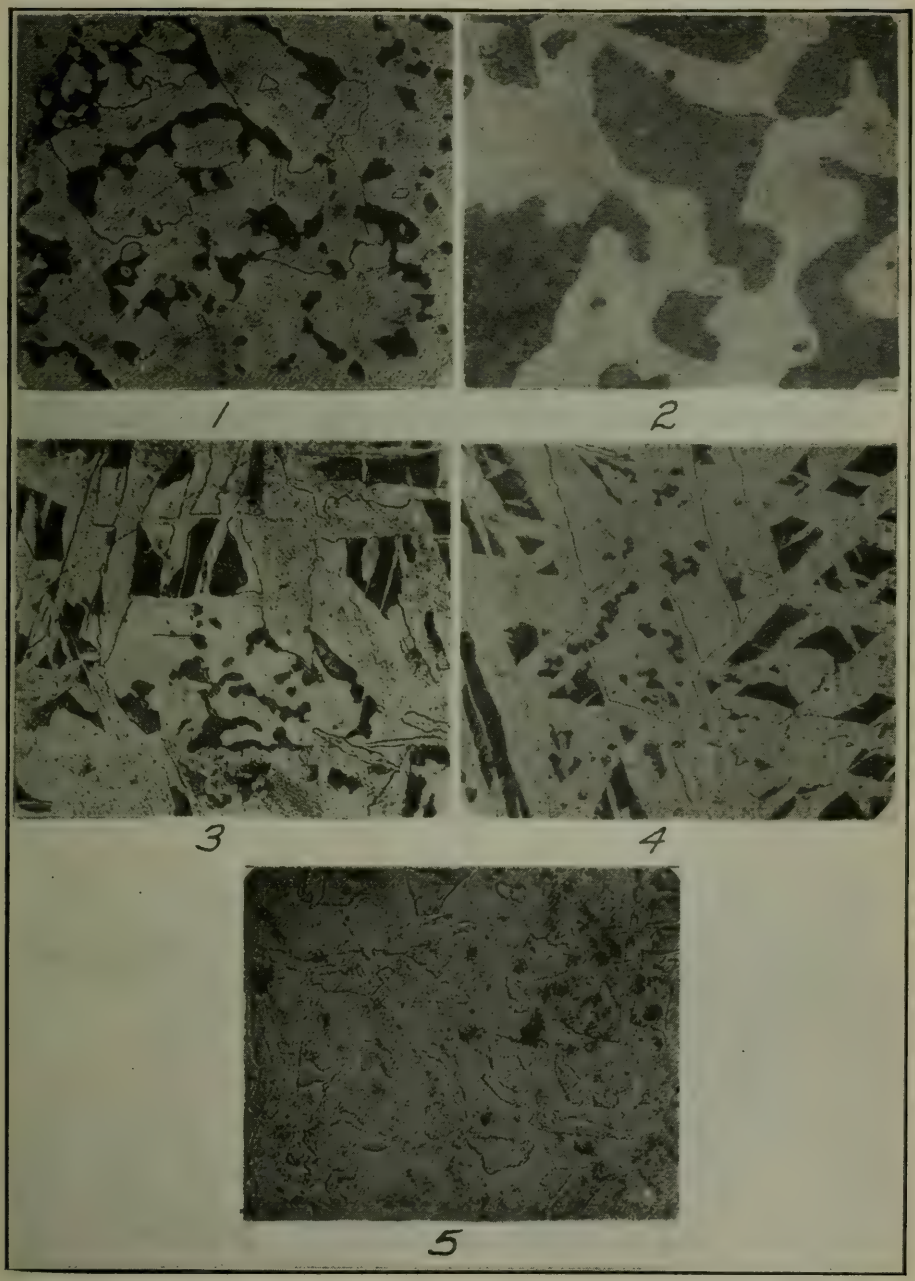
Bar No.	Elastic Limit Lbs. per sq. in.	Ultimate Strength Lbs. per sq. in.	Reduction Area Per Cent	Elongation Per Cent	Elastic Limit / Ultimate Strength Per Cent
1A	25,250	55,150	40.3	29.0	46.1
1B	25,500	55,450	39.7	32.0	46.1
Average	25,375	55,300	40.0	30.5	46.1
2A	21,125	55,600	32.4	26.5	37.9
2B	23,875	55,575	33.1	27.5	42.6
Average	22,500	55,587	32.7	27.0	40.2
3A	25,000	56,175	26.8	20.5	44.5
3B	20,100	56,650	32.8	24.5	36.5
Average	22,550	56,412	29.8	22.5	40.5
4A	21,350	41,875	15.2	5.0	51.2
4B	20,750	52,650	9.2	7.0	39.5
Average	21,050	47,272	12.2	6.0	45.3
5A Blocks were defective, thus preventing the machining of test bars.					
5B					
Grand Average	22,869	53,643	28.7	21.5	43.0

As will be observed in reviewing the above table, the elastic limit averaged 22,869 pounds per square inch, varying from a minimum of 21,050 to a maximum of 25,375 pounds per square inch. The ultimate strength averaged 53,643 pounds per square inch, varying from a minimum of 47,272 to a maximum of 56,412 pounds per square inch. The reduction of area varied consistently from 12.2 per cent to 40.0 per cent with an average of 28.7 per cent. The percentage of elongation varied from 6.0 per cent to 30.5 per cent with an average of 21.5 per cent. The ratio of the elastic limit to ultimate strength showed an average of 43.0 per cent with a variation from 40.2 to 46.1 per cent.

It is readily seen that for all practical purposes there is no variation in the elastic limit, ultimate strength and hence none in the relative ratios, all variation caused by pouring temperatures exhibiting itself in reduction of area and elongation variations. The latter quite consistently follows an even descending curve when plotted against increasing temperatures.

Photomicrography

Fig. 1 and 2 shows the structure of series I. It will be observed in Fig. 1 that the structure is large grained and irregular with many dark island areas which at 400 diameters magnification are seen to be composed of sorbite embedded in a ferrite matrix. The sorbitic structure is typical of the dark



PHOTOMICROGRAPHS OF CAST STEEL

Fig. 1—Photomicrographs of test specimen of series 1 cast at 2678 degrees Fahr. × 100. Fig.2—Photomicrograph same as Fig. 1 × 400. It will be observed that the structure is large grained and irregular. The dark island areas are sorbite embedded in a ferrite matrix. This sorbitic structure is typical of the dark areas of the remaining Figs. Figs. 3, 4 and 5 show a very marked Widmanstatten structure and have been photographed at 100 diameters magnification. Fig. 3 represents series 2 cast at 2699 degrees Fahr. Fig. 4 represents series 3 cast at 2732 degrees Fahr. Fig. 5 represents series 4 cast at 2771 degrees Fahr.

areas of the remaining series, hence these series are shown in Figs. 3, 4 and 5 at 100 diameters magnification. It will be observed that in Figs. 3, 4 and 5 a very marked Widmanstatten structure exists, which is considered by several leading metallographists to be the typical structure of cast steel. Fig. 5 shows a specimen from series 4 and it will be seen that it is filled with many minute blowholes which were invisible to the naked eye. This condition is the logical fore-runner of the large blowholes which were noted in series 5.

Conclusions

In conclusion, it seems that, provided the mold is cooled sufficiently slowly from the molten state of the metal, a Widmanstatten structure will result. This structure is not of the strongest, is rather brittle, and therefore, should be avoided. The physical results prove this, as both the reduction of area and elongation decrease as the quantity of this structure increases.

In a previous treatment of this same problem, the tensile tests of which proved valueless because of the inaccuracy of an only available tensile machine, the author performed a similar experiment as here, except that the blocks were stripped as soon as they became solid enough, and were cooled in air. A Widmanstatten structure here exhibited itself, but the planes of symmetry were not as well marked as in the present case, the straight lines and lanes being curved due to the more rapid cooling.

By annealing this latter set of similar specimens at just above their critical point for 20 minutes, this objectionable structure was broken down completely, the result being a well defined pearlite. On a drawback to 400 degrees Cent., typical troostite developed.

Although the physical results of this latter set were so very inaccurate as to render them valueless, the author's experience has shown that the Widmanstatten structure can be effectively broken down by a simple anneal just above the Ac_3 point for sufficient time, depending on the section of the casting. The ultimate strength will increase to about 80,000 pounds per square inch and the elastic limit to between 40,000 and 50,000 pounds per square inch for a steel of the analysis under consideration. The grain size will be small, and will be composed principally of sorbite and ferrite, with the possibility of pearlite.

Thus, the annealing of such castings is the problem of the heat treater, provided the castings are not poured so hot as to render the steel wild and full of blowholes. No holes being present, the heat treater can produce a standard, uniform product, irrespective of the structure of the poured casting.

To the foundryman who, as a rule, does not anneal his castings, it is to his advantage to pour his castings at as low a temperature as possible, having due regard to the proper running of his steel. It may be stated here, that we, as steel treaters, realize the advantage of annealing to improve the cast steel product as a regular part of the foundry routine.

MIGRATION OF CARBON FROM STEEL TO INGOT IRON[1]

By O. Z. Klopsch and H. F. Roberts

Abstract

This paper points out the possibilities of obtaining quantitative results of the rate of migration of carbon from steel to ingot iron, and its depth of penetration. That such migration will take place has been known for some time, but the difficulties encountered in obtaining quantitative results, has probably hindered similar investigations.

It was necessary that the authors discontinue their work at a time when the solution to the major part of their difficulties seemed likely and it is hoped that the suggestions offered here will aid those desiring to carry on investigations of similar nature. The results obtained by the present authors, while still being incomplete, show definitely that there is a transfer of the carbon from the steel to the carbonless ingot iron. Photomicrographs and curves illustrate the work so far accomplished.

IN THE November, 1920, issue of the *Journal of Industrial and Engineering Chemistry*, E. G. Mahin and E. H. Hartwig of the department of chemistry, Purdue University, published a paper entitled "Inclusions and Ferrite Crystallization in Steel." In this paper they proved quite conclusively that under certain conditions of contact and temperature carbon can be made to migrate from a carbon steel to ingot iron.

Based upon this premise the authors of the present paper proceeded to determine the rate of migration and the depth of penetration of carbon which takes place between eutectoid carbon steel and ingot iron when heated at various temperatures and for various periods of time.

Procedure

In planning this work it was realized that it was necessary to have extremely close contact between the ingot iron and the steel and in order to accomplish this a hollow cylinder of ingot iron was carefully drilled, and a plug of 0.835 per cent carbon steel 0.003 inch larger in diameter than the opening in the cylinder was carefully prepared. The ingot iron cylinder was then expanded by heating to a temperature of 600 degrees Cent. (1112 degrees Fahr.) and the cold plug was quickly driven in.

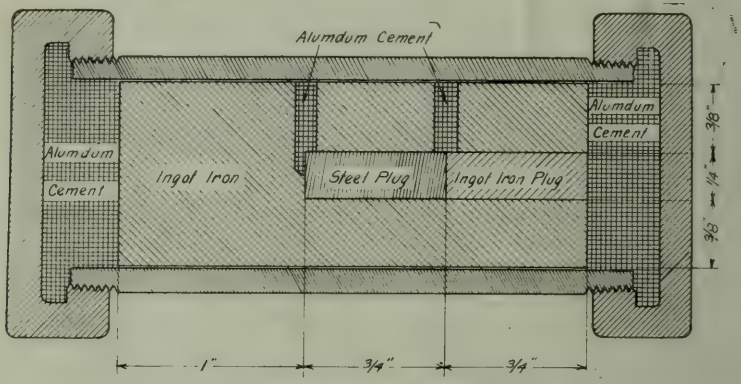
It was found that while the ingot iron filled in the machining and drilling imperfections fairly well, some scale formed on the cylinder due to oxidation on heating for expanding, which probably played some part in removing carbon from the eutectoid plug. Probably a better way to obtain good contact and exclude oxidation would have been to have the hole in the cylinder slightly tapered, with a corresponding taper on the plug, so that a driving fit could be obtained, resulting in a more intimate contact between the cylinder and the plug.

In order to prevent the escape of carbonaceous gases a cylinder was drilled part way through longitudinally and the steel plug was inserted and a plug of ingot iron used to seal the drill hole. Small vent holes were drilled to allow an

1. Submitted as a part of a thesis for the degree of Bachelor of Science in Metallurgical Engineering, Case School of Applied Science, Cleveland, O., 1922.

escape for the air behind the plugs; these holes being closed with alundum cement. Fig. 1 shows a sketch of this arrangement and the manner in which it was enclosed in a short length of standard 1-inch pipe, which was provided with caps at each end; thus this container assisted in limiting the amount of air coming in contact with the test specimen and so helped prevent the escape of carbonaceous gases from the specimen of steel.

By excluding oxygen, it was hoped that the migration of carbon would take place from solid to solid without the use of a gas as a medium, but the evident presence of oxygen due to scale and oxide inclusions in the ingot iron,



Air Behind the Plugs

Fig. 1—Sketch Showing Arrangement of the Steel and Ingot Iron Plugs Inserted in the Ingot Iron Cylinder. Small Vent Holes Were Drilled to Allow an Escape for the Air Behind the Plugs

makes it impossible to say how the carbon did actually migrate. The partial decarburization of the plug and the apparent failure to find sufficient carburization of the cylinder to account for this, indicates that some carbon may have been lost by combination with the oxides.

Where close contact was obtained the carburization of the cylinder seemed to approximate the decarburization of the plug, while in samples where this condition was not obtained, either no carburization of the cylinder or very little took place, although the plug had been quite materially decarburized.

Methods of Heating Specimens

In the operation of shrinking the steel plug into the ingot iron cylinder, a gas-fired, muffle type furnace was used. Temperature measurements were made with a pyrometer.

The heating of specimens at the migration temperatures was carried on in electric furnaces of the resistance type. Three different combinations were used in this heating, the choice being governed by the time that the specimens were at temperature. The first combination was a verticle muffle resistance furnace manually regulated with a rheostat, using base metal thermocouples and a potentiometer. The second combination was a muffle type furnace using the hairpin type of resistance heating units. A low-resistance voltmeter was used in conjunction with a base-metal thermocouple for obtaining temperature measurements. This furnace was used in runs requiring a temperature of 900 degrees Cent. (1652 degrees Fahr.) or more. The third combination, used for long runs, was a verticle muffle resistance furnace automatically controlled with an automatic temperature recorder attached.

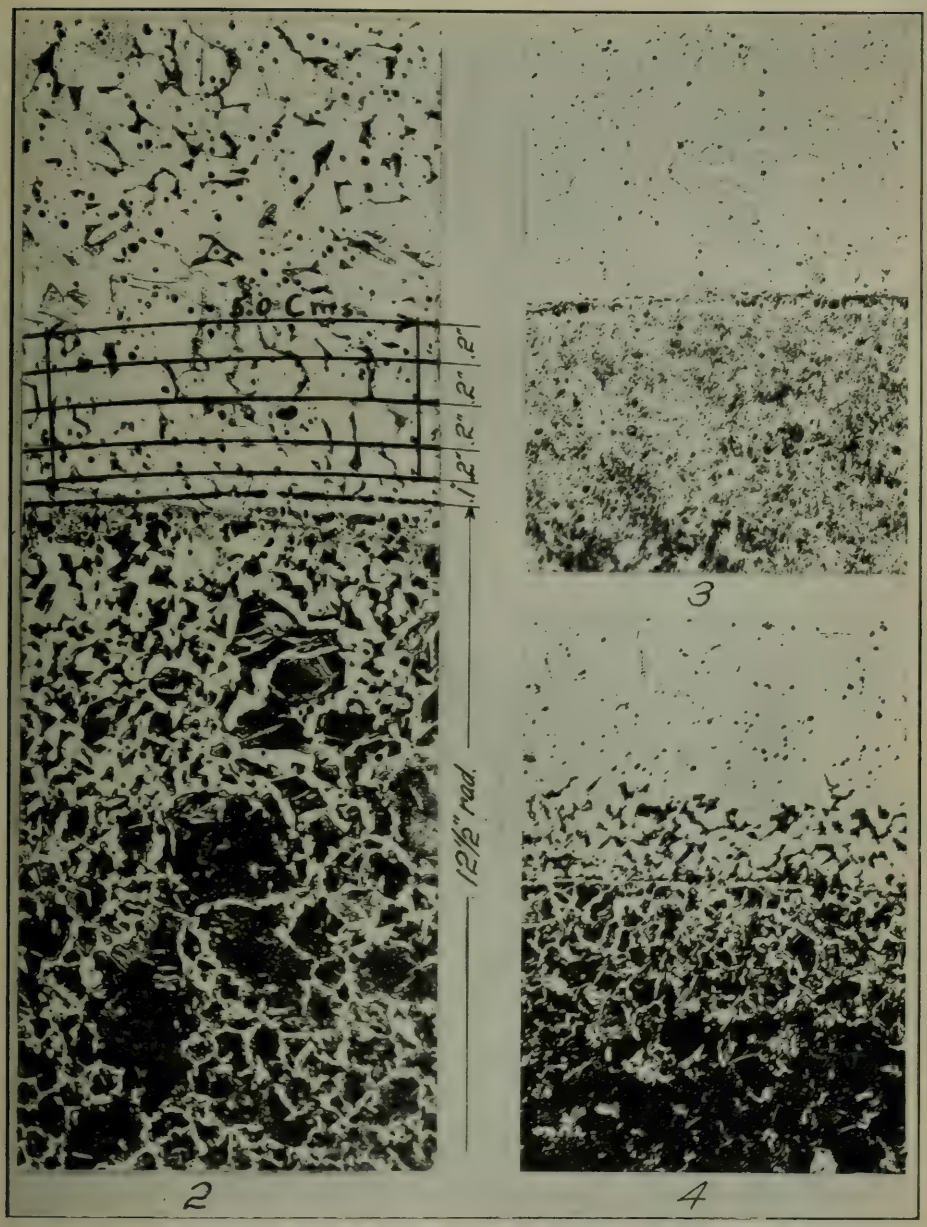


Fig. 2—Photomicrograph illustrating the method of determining the pearlite content of the ingot iron after heating; Fig. 3—Photomicrograph of Specimen X which was heated for 48 hours at 650 degrees Cent. (1202 degrees Fahr.); Fig. 4—Photomicrograph of Specimen A heated for eight hours at 800 degrees Cent. (1472 degrees Fahr.). All magnifications × 100.

Temperature Used

The temperatures used to obtain migration were above the Ac_3-$_2$-$_1$ range of the eutectoid plug and above the Ac_2 point of the ingot iron surrounding

the plug. These ranges were determined on a standard transformation point recorder, with the following results.

Ingot iron Ac_2 = 765 degrees Cent., (1409 degrees Fahr.)

Ac_3 = 908 degrees Cent., (1666 degrees Fahr.)

Eutectoid steel Ac_{3-2-1}=765 degrees Cent., (1409 degrees Fahr.)

After determining experimentally that no migration took place in 48 hours

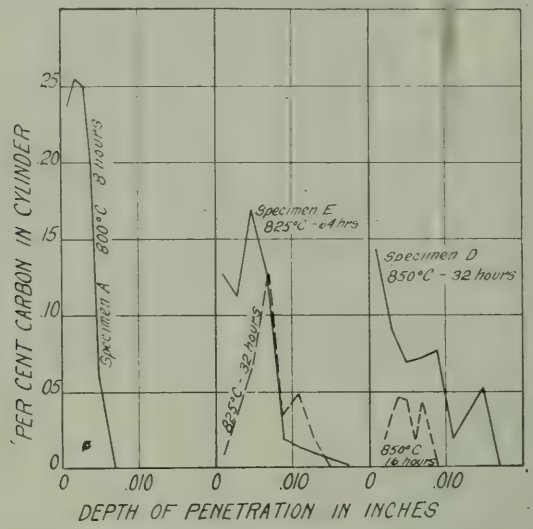


Fig. 5—Carbon Penetration Curves for Specimens A, D and E Heated at 800, 850 and 825 Degrees Cent., Respectively

at a temperature of 650 degrees Cent. (1202 degrees Fahr.) temperatures above the critical ranges were then used.

In order to determine quantitatively the amount of carbon which had migrated, the samples were cut transversely, polished, etched and photographed at at 100 diameters magnification.

Determining Amount of Penetration of Carbon

The photomicrographs were examined by a comparator which is comprised of two microscopes sliding on a bar over a finely divided scale. By this means measurements were made of the linear dimensions of the pearlite areas where they were cut by arcs of concentric circles drawn using as a center of radius the center of the plug. Since the photographs were taken at 100 diameters and the core is 0.125 inch in radius, the imaginary center of the core will be 12.5 inches from the concave side of the edge of the core shown on the prints. This method is shown in Fig. 2.

The amount of carbon which had migrated into the cylinder was determined at 0.1 to 0.5-inch intervals on the print (actually .001 to .005 inch on the specimen) on arcs swung from the established center. The determination was made by taking the sum of the linear dimensions of the pearlite areas where they had been cut by the arcs and multiplying by the factor of carbon in pearlite (.0085) to get the amount of carbon. The sum of the linear dimensions of the pearlite grains multiplied by .0085 and divided by the length of the arc considered, gave of course, the fractional carbon content of the field at the zone cut by the arc. Having determined the amount of carbon in each zone it

was then possible to plot the percentage of carbon against the depth of penetration, with temperature and time, a constant. Carbon penetration curves for specimens A, B, C, D, and E are shown in Figs. 5, 6 and 7.

From the amount of pearlite found, the carbon at each interval of space from the junction could be readily calculated. These amounts when plotted

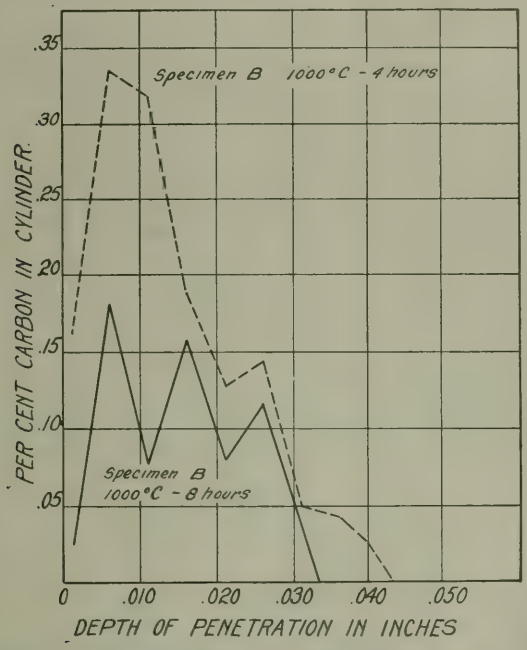


Fig. 6—Carbon Penetration Curves for Specimen B Heated at 1000 Degrees Cent. for Eight Hours

showed a surprising regularity, indicating that a very close determination could be made, with sufficient time and care.

Specimen X shown in Fig. 3 shows that no migration was obtained at a temperature of 650 degrees Cent. (1202 degrees Fahr.) for 48 hours. It will be noted from the photomicrograph that the mechanical bond was very good and therefore it was concluded that no migration across the boundary took place at this temperature with the time interval used. There is a considerable increase of free ferrite in the peripheral part of the eutectoid plug, which is difficult to explain.

Specimen A shown in Fig. 4 heated at a temperature of 800 degrees Cent. (1472 degrees Fahr.) for a period of 8 hours gave a uniform curve of the type found generally throughout this problem. This was the lowest temperature above the Ac_3-$_2$-$_1$ range of the steel plug at which it was attempted to obtain migration. The bond here is excellent and the pearlite has migrated uniformly into the ingot iron.

Specimens E_1 and E_2, Figs. 8 and 9, were heated at a temperature of 825 degrees Cent. (1517 degrees Fahr.) for 32 and 64 hours respectively. While thy show a greater decarburization of the plug and a greater depth of penetration of pearlite into the cylinder, they have a less complete bond between the plug and the cylinder than specimen A and the amount of migrated pearlite is not so great.

A temperature of 850 degrees Cent. (1562 degrees Fahr.) was used in heating specimens D_1 and D_2. Specimen D_1 was heated for 16 hours and specimen D_2 for 32 hours. These are shown in Figs. 10 and 11 respectively and show an inferior mechanical bond. Here it will be noted that the penetration curves for specimens E_1 and D_2 are very similar, as might be expected with a diffrence of temperature of only 25 degrees Cent. but on examination

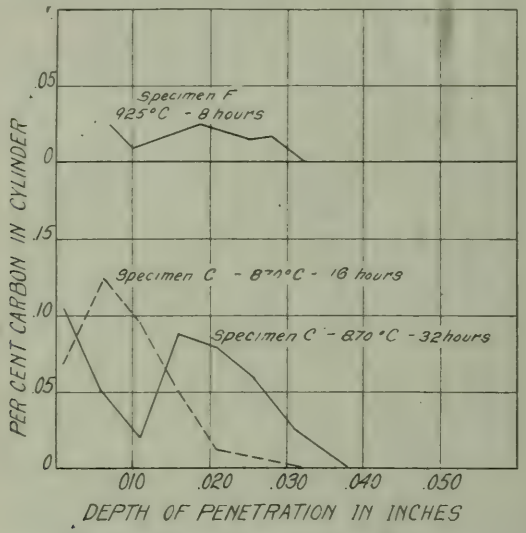


Fig. 7—Carbon Penetration Curves for Specimens C and F Heated at 870 and 925 Degrees Cent., Respectively

of the photomicrographs, D_2 plug is seen to be more decarburized. Specimen D_1 does not compare favorably with either specimen A, which was heated 50 degrees Cent. lower in temperature and one half as long, or with specimen D_2 which was heated to the same temperature. Its decarburization compares fairly well, but the lack of uniformity in the carburization of the cylinder shows up plainly and shows the effect of poor contact.

Specimens C_1 and C_2, Figs. 13 and 14 were heated to a temperature of 870 degrees Cent. (1598 degrees Fahr.) for 16 and 32 hours respectively. They show a very distinct band of oxide at the bond, which necessarily must mean a poor contact between the plug and the cylinder. Specimen C_1 plug shows the least decarburization of any with the possible exception of specimen A, while the depth of penetration is greater, as might be expected at the increased temperature. The pearlite seems to be better distributed throughout the cylinder, that is, the concentration is less than at corresponding points in specimens D_1 and D_2 so that the curve is considerably flatter.

Specimen F, Fig. 12 gives very poor results as far as the carburization of the cylinder is concerned, but seems to compare with the other specimens as regards the decarburization of the plug. In this specimen as in the others the large number of sonims will be noticed and these may play an important part in the lack of consistency of many of the results. The pearlite appears to have penetrated the deepest into the ingot iron in this specimen although, there is very little of it. This suggests that perhaps at this high temperature when the carbon or carbide came in contact with an inclusion it was oxidized and removed. The deep penetration occurring with such a small concentration

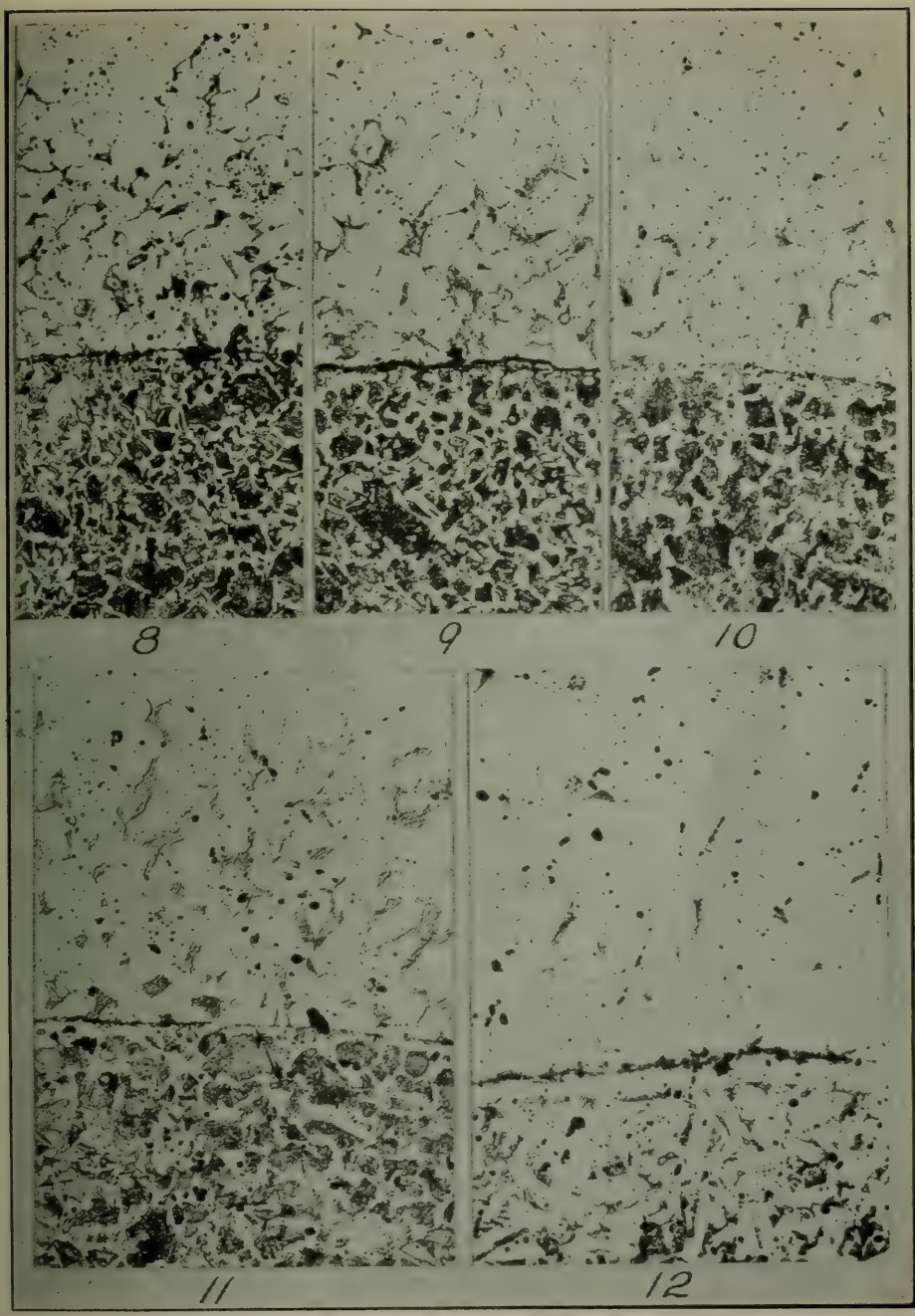


Fig. 8—Photomicrograph of Specimen E_1 heated 825 degrees Cent. (1517 degrees Fahr.) for 32 hours; Fig. 9—Photomicrograph of Specimen E_2 heated to 825 degrees Cent. (1517 degrees Fahr.) for 64 hours; Fig. 10—Photomicrograph of Specimen D_1 heated to 850 degrees Cent. (1562 degrees Fahr.) for 16 hours; Fig. 11—Photomicrogrph of Specimen D_2 heated to 850 degrees Cent. (1562 degrees Fahr.) for 32 hours; Fig. 12—Photomicrograph F heated to 925 degrees Cent. (1697 degrees Fahr.) for eight hours. All magnifications × 100.

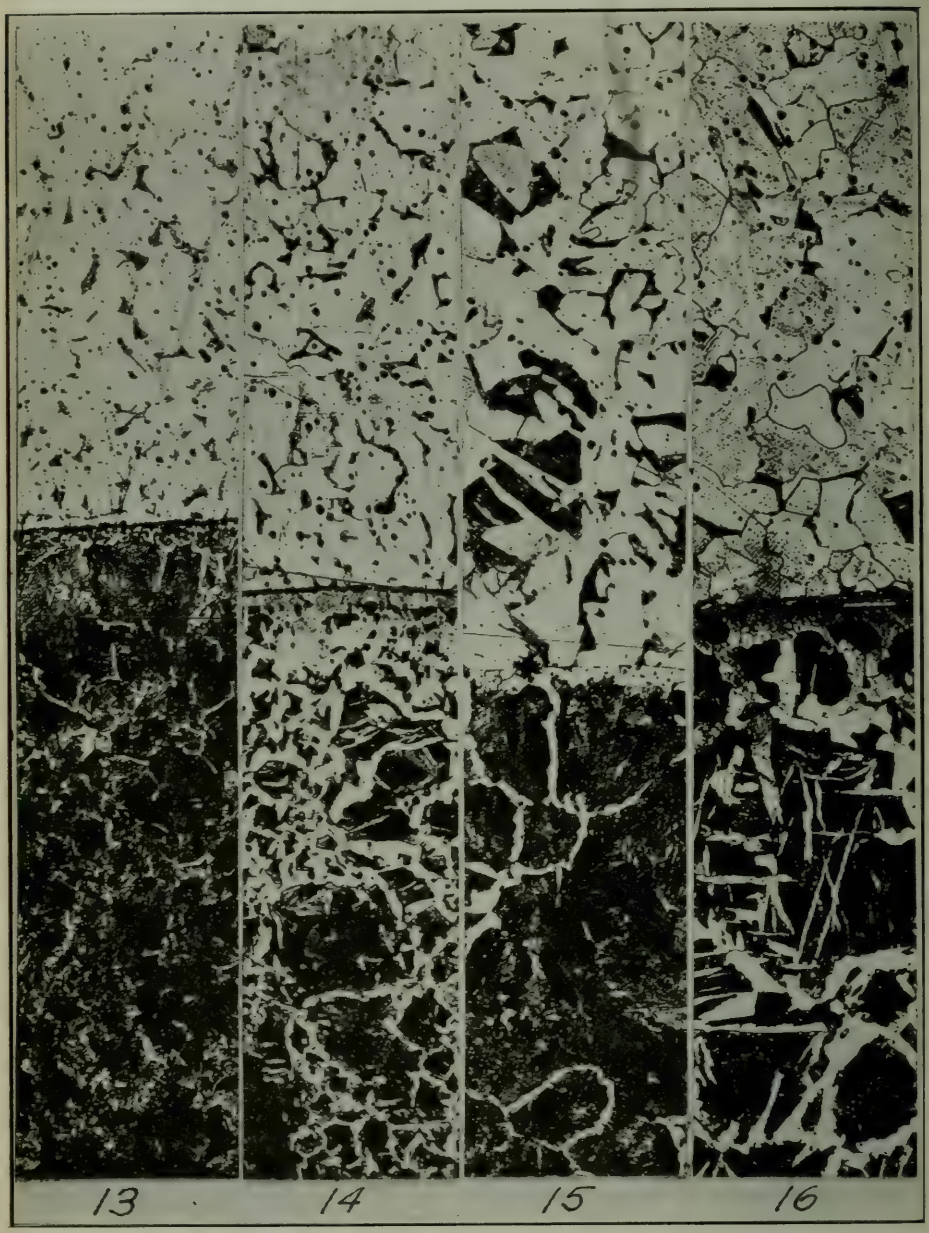


Fig. 13—Photomicrograph of Specimen C_1 heated to 870 degrees Cent. (1598 degrees Fahr.) for 16 hours. Fig. 14—Photomicrograph of Specimen C_2 heated to 870 degrees Cent. (1598 degrees Fahr.) for 32 hours. Fig. 15—Photomicrograph of Specimen B_1 heated to 1000 degrees Cent. (1832 degrees Fahr.) for four hours. Fig. 16—Photomicrograph of B_2 heated to 1000 degrees (1832 degrees Fahr.) for eight hours. Magnifications of all specimens × 100.

seems to indicate that some carbon had escaped contact with any inclusions and therefore had not been removed, and since the time at the temperature had been sufficient the carbon had migrated to this greater depth.

Specimens B_1 and B_2, Figs. 15 and 16, heated at 1000 degrees Cent. (1832 degrees Fahr.) for 4 and 8 hours respectively, show the maximum depth of migration of all the specimens, however, specimen B_2, which was held for 8 hours, shows a lesser peneration than specimen B_1, which was heated 4 hours. One might almost think that the samples had been interchanged, but on examination of the photomicrograph it is easy to see that this is not the case as the grain size of specimen B_2 is much larger than Specimen B_1 and a greater amount of decarburization of the plug has taken place. It will be noticed that specimen B_2 has a black border at the junction while specimen B_1 has a good clean molecular contact. This is probably the explanation for this irregularity.

Discussion and Summary

As evidenced by the results obtained in this investigation uniformly good mechanical bonds between the steel plug and the ingot iron cylinder seem to be essential for consistent results where the difference in time at heat for the specimens of a series is comparatively small. The exclusion of oxygen likewise is imperative.

A migration of carbon takes place between the steel plug and ingot iron cylinder above the A_3-$_2$-$_1$ range of the eutectoid steel plug and above the A_2 range of the ingot iron cylinder. Migration does not take place below the critical ranges at the temperature and time used in these experiments.

Although some of the results obtained are not explainable, however, most of them show a fairly well defined curve for the rate and depth of migration. The best results were obtainable at the higher temperatues, where a greater degree of migration takes place.

In summarizing the results of this investigation we find that they may be stated in the following seven divisions.

1. With close physical contact, oxygen being excluded, fairly accurate quantitative results are obtainable as to the amount of migration and the depth of penetration of carbon into ferrite.

2. A tapered plug driven into a tapered hole with considerable pressure should give better results than a cylindrical plug shrunk into a ring, when such shrinking causes oxidation.

3. Heat-treating the specimens in a vacuum would eliminate the presence of oxygen from without and do away with loss of carbon in that manner.

4. The iron cylinder should be as free from oxide sonims as possible to eliminate any possibility of carbon loss.

5. Migration of carbon takes place from the steel plug to the ingot iron cylinder at temperatures above the Ac_3-$_2$-$_1$ range of the plug in measurable quantities.

6. A plug of hyper-eutectoid steel or silicon-free hard iron might be used in order to eliminate free ferrite, so that the decarburization of the plug can be used as a quantitative means of determining the carbon migration as well as the carburization of the surrounding cylinder.

7. A large number of cross sections should be taken on each specimen and the pearlite intercepted by circles drawn with the center of the plug as a center, should be measured on the entire circle in order to get the best average results. Longitudinal sections would also probably aid in getting better average results.

NOTES FROM THE BUREAU OF STANDARDS

Effect of Ammonia on the Surface of Steels of Increasing Carbon Content

IN co-operation with the Fixed Nitrogen Research Laboratory, the bureau made a microscopic examination of specimens representing a series of steels varying in carbon content from 0.02 to 0.98 per cent exposed to a current of ammonia at temperatures in the range of 100 to 700 degrees Cent. The purpose of this test was to determine the effect of change in carbon content upon the method of attack of heated ammonia. No change was observed on the specimens up to 400 degrees Cent.; at 500 degrees Cent. a film of white nitride was followed by the layer of nitride needles. At 600 degrees Cent. this effect increased, while at 700 degrees Cent. a new compound of nitrogen was formed following directly the film of white nitride layer. At 700 degrees Cent. with two low carbon steels the nitride needles removed further from the edge to the center. They are absent at that temperature in high carbon steels of 0.49 to 0.98 per cent carbon. Twelve micrographs were taken and a detailed report submitted to the Fixed Nitrogen Laboratory.

Investigation of Invar—36 per cent Nickel Steel

A study has been made of the ingot structure of the small ingots cast for this investigation, and the relation of the structure to the forgeability of the alloy. It has been found that although the ingots have been cast in chilled molds, the rate of cooling is not sufficiently rapid to prevent the formation of excessively large columnar crystals producing a very brittle ingot which breaks readily on forging.

As a result of these tests, ingots will be cast in water-cooled molds to increase the rate of cooling and thus prevent, if possible, the formation of the large columnar structure, making the ingots more readily forgeable.

Wear Test of Steel

The investigation of the resistance to wear of steels has been previously mentioned and variations in wear caused by different arrangement of the apparatus has been described.

During the past month a study has been made of the effect of keeping the surfaces of the specimens clean and free from all adhering abraded particles. A cloth buffing wheel, rotated at high speed by an electric motor, has been used successfully for this purpose. It has been found that when the wearing surfaces are thus kept free of abraded metallic dust, the rate of wear drops to an almost negligible quantity compared with the rate when the wearing surfaces are not kept clean by the buffing wheel.

Enameling Properties of Cast Iron

As it has been claimed that gray cast irons, for example, such as are used for bath tub castings, vary widely in their enameling properties, the bureau has been examining specimens of this class of iron to determine wherein the differences lie. Twenty specimens of cast iron were secured from different manufacturers and examined as to microstructure, but no differences which could be considered of importance in affecting their enameling properties have been found. The work, however, will be continued.

Testing of Steel Hoisting Rope

Methods of testing steel hoisting rope and of inspecting such rope in service to determine when it needs replacement are subjects in which mining

and elevator companies are much interested, and the bureau has been asked to undertake an investigation to determine practicable methods for such testing and inspection. A member of the bureau's staff presented a paper on the subject at the meeting of the American Institute of Mining and Metallurgical Engineers on Feb. 21, 1923, and plans for the proposed investigation are under discussion with the bureau of mines and other interests concerned. In anticipation of a small appropriation for carrying on this work during the coming fiscal year, the bureau is making plans to begin intensive work on the problem as soon as possible.

Inview of the nature of the inspection desired, any test which may be developed must be nondestructive. Of all such tests so far considered, magnetic analysis appears to show the greatest promise, and consequently this method will be given first attention. The paper referred to above will be published in the *Transactions* of the American Institute of Mining and Metallurgical Engineers.

Tests of Welded Tanks

The investigation of the strength of about 50 tanks, some of which had been welded by gas and some by electricity, has been completed. This work, which was carried out in co-operation with the American Bureau of Welding, was begun on Dec. 4 and completed on Feb. 9, and gives reliable information on the strength of welded tanks for the consideration of the pressure vessel committee of the boiler code committee of the American Society of Mechanical Engineers.

The results showed that double-V longitudinal welded seams are much stronger and more reliable than single-V welds. Recommendations were also made covering the design and construction of the heads. The pressures at which these tanks failed were so high that confidence in the safety of welded tanks which are properly constructed has been greatly increased. The method of testing, by hammeriing the weld while the tank is under pressure of one and one-half times the working pressure, was discussed. Although this test did not prove as effective in showing up defective welds as had been hoped, its use is, nevertheless, justified.

Another acceptance test proposed in this report is to increase the pressure until the shell of the tanks reaches the yield point. These tests show that the tanks are safe after being tested in this way. As it is probable that tanks having large outlets would be seriously deformed, and therefore, rendered unserviceable, this test is not likely to be adopted, but an increase in the test pressure will probably result.

It is especially commendable to note that the Bureau of Welding, which represents one of the youngest of the engineering industries, has a large number of important problems which it expects to solve. Their importance will be realized when it is considered that they effect almost every one because of the waste of material which results when designs are based on insufficient data or are influenced by prejudice.

Head and Eye Safety Code

The second edition of the National Safety Code for the protection of the heads and eyes of industrial workers has come from the press, and copies can be secured from the superintendent of documents, government printing office, Washington. The first edition of this code was completed in 1920 and has found wide application in the industries which call for protection to the eyes of workmen. Protection of this sort is needed in work such as chipping,

riveting, grinding, stone dressing and other operations where small flying particles are common; in processes where splashing metal, fumes and caustic chemicals are encountered, and in acetylene and electric welding and furnace work where the eye cannot be exposed to sources of intense heat and light.

The revision of the code was carried out by a sectional committee of the American Engineering Standards committee which consisted of 25 representatives of the various interests involved, such as state officials, employers, employes, insurance companies, and manufacturers. The chairman of the committee was Dr. L. R. Thompson, of the United States public health service, and the secretary was Dr. M. G. Lloyd, of the bureau of standards.

Carburization of Steel

An investigation of the effect of the quality of steel upon its carburizing properties and particularly its hardening properties after carburization was suggested to the bureau of standards by commercial metallurgists as a problem of very considerable commercial importance. In order to obtain a wider expression of opinion on this matter, a circular letter was sent to approximately 100 prominent metallurgists. The replies which have been received all indicate the desirability of carrying out such an investigation and the practical importance which the results would have. As soon as the necessary material (abnormal steels) can be obtained, the work will be started.

Gases in Monel Metal

The bureau has just completed determinations of oxygen and hydrogen in samples representing three phases of the deoxidation of monel metal. The samples were all from 50-pound blocks cast during the progress of a regular heat. These samples represent (1) the metal at the time of tapping the furnace before the addition of any deoxidizers; (2) the above metal after the addition of ferromanganese in the ladle, and (3) the above metal after the further addition of magnesium in the ladle, that is, after all additions have been made. Both oxygen and hydrogen in the metal decreased rapidly with the progress of the deoxidation. The finished metal, as represented by the last sample of this heat and by samples of completely deoxidized metal from two other heats, contains from 0.002 to 0.005 per cent oxygen. All samples appear rather porous under a magnification of 100.

A sample of monel metal prepared as above, except that a portion of the deoxidation was carried out in the furnace rather than entirely in the ladle, showed no porosity, and no oxygen could be detected. A sample of monel metal from a Herault furnace heat, which had been completely deoxidized in the furnace, likewise was entirely sound and contained no oxygen. Thus, of the five samples of finished monel metal examined, the three which were deoxidized by addition of ferromanganese and magnesium in the ladle were porous and contained from 0.002 to 0.005 per cent oxygen, while the two which were deoxidized entirely or in part in the furnace were sound and contained no oxygen.

Solders for Aluminum

Circular No. 78 of the bureau of standards entitled, "Solders for Aluminum," has recently been revised. It will soon be available from the superintendent of documents, government printing office, Washington, D. C.

Most of the metals commonly used in solders, except magnesium, are electro-positive to aluminum, so that any metals used in making a soldered

joint of aluminum act electrolytically in the presence of moisture as positive galvanic poles accelerating the corrosion of the aluminum. Magnesium cannot be utilized advantageously even though it is electro-negative to aluminum because the metal disintegrates rapidly in the presence of moisture. Therefore, soldered joints of aluminum which are to be exposed to moisture should be protected against corrosion by paint or varnish. Various compositions of zinc-tin and zinc-tin-aluminum solders give the best results.

The tensile strength of a good aluminum solder is about 7000 pounds per square inch because those with higher tensile strength usually have such a high temperature of complete liquidation that they are unsuited for soldering purposes. As a rule, the strength of an aluminum soldered joint depends upon the type and workmanship.

Tests of Welded Rail Joints

Two welded 7-inch rail joints were recently tested for the Welded Rail Joint committee of the American Electric Railway association and the American Bureau of Welding. One of the joints, a thermit weld, failed at an ultimate load of 600,000 pounds. The other joint, of the welded fish-plate type, failed at about 200,000 pounds. Transverse tests were also made on similar welds. These tests illustrate the methods which will be used in testing several hundred joints representing the types at present in use in this country.

Recent Publications of the Bureau of Standards of Especial Interest to our Readers

S 463 Preparation and properties of pure iron alloys: II. Magnetic properties of iron-carbon alloys as effected by heat treatment and carbon content. W. L. Cheney.

S 464 Preparation and properties of pure iron alloys: III. Effect of manganese on the structure of alloys of the iron-carbon system. Henry S. Rawdon and Frederick Sillers Jr.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

NEW QUESTIONS

QUESTION NO. 78. Does microscopic or macroscopic examination of a fatigue failure indicate, even approximately, how long the crack has been forming, or how many times the stress was applied during the growth of the crack?

QUESTION NO. 79. Does the apparent grain size of a fatigue fracture vary with the load applied to cause failure, or with the fatigue strength of the material?

QUESTION NO. 80. Does a banded fatigue fracture indicate interruptions in the growth of the crack?

QUESTION NO. 81. How can you distinguish between a fatigue failure in ductile metal and a sudden failure in a metal which was brittle at the time of the rupture?

ANSWERS TO OLD QUESTIONS

QUESTION NO. 27. What is the function of the high phosphorus and the high sulphur content in the so-called automatic screw stock steel?

ANSWER. By C. T. Patterson, metallurgist with the Solvay Process Co., Syracuse, N. Y.

High phosphorus and high sulphur cause the chip to break up easily so that it will not clog the machine. Phosphorus is dissolved in the metal, not uniformly but concentrated in patches or individual grains, each of such grains being relatively brittle.

High sulphur must always be accompanied by high manganese or the steel cannot be rolled. The manganese and sulphur form nonmetallic globules or drops of manganese sulphide which may be drawn out in rolling. This sulphide is very much weaker than the steel and is quite brittle and whenever it occurs in a chip a break is also almost certain to occur.

QUESTION NO. 59. Is a sulphur content of 0.067 per cent detrimental to the proper carburizing of a low carbon steel having a low manganese and phosphorus content?

QUESTION NO. 64. To what extent can the deep etching of specimens of steel be applied to routine examination of incoming material?

ANSWER. By H. G. Keshian, metallurgist with the Waterbury Mfg. Co., Waterbury, Conn.

This method of inspecting steel has its advocates as well as its opponents. Some of the steel companies are not inclined to accept it, but there are others who favor it and are selling their products subject to deep etch test. The method, of course, is comparatively a new one and like every new idea has its handicaps and imperfections and consequently some of the conclusions derived from its application are subject to dispute. But this is to be expected and it is rather desirable that it should be so, for opposition of this nature not only will help to improve the method, but it will also prevent some of us from carrying it to the extreme, a tendency which seems to be closely associated with everything new.

The deep etch, when properly and carefully applied, is of great value in revealing the structural condition of steel. It is a quick method of inspection whereby seams, blow-holes, segregations, pipes, cracks and similar defects can be detected. One great and perhaps main difference between the deep etch test and other methods of inspection is this. In other methods, for instance, the tensile test, hardness tests or chemical analysis, certain limits can be set and these limits can be expressed in numerical values and any material showing values outside of these limits can be rejected. With the etch test, however, definite limits cannot be established. The amount or the extent of various defects when disclosed by the etch test vary greatly and at times some of these defects are so small that it is quite difficult to draw the line of demarcation between a satisfactory and unsatisfactory piece of steel and the question in a case like that simply resolves itself to a mere matter of opinion. Yet this difficulty is not as great a shortcoming to the etch tests as it may appear and any such controversy can easily be settled by good judgment and fair play in the light of mutual benefit.

In the course of time we will know more about the value and the limitations of the method by the aid of our increased knowledge on the life of tools and parts made from steels possessing various structures as revealed by the etch test. In other words, we must judge the value of the etch test like any other test in its relation to the life or the tool or as commonly known, the service test, and in order to improve the method to its highest stage of usefulness the facts obtained by means of the etch test and service test should by all means be correlated.

According to the writer's experience with the method for some years it is safe to say that the method is an exceedingly valuable one as a means of detecting defective steels before they are made up into tools and machine parts. It is also his experience that no matter how satisfactory the material may be from the standpoint of chemical analysis and no matter in what reputable steel mill the material has been manufactured unless such a test is applied to the steel there is a constant danger for some material of defective structure slipping into the tool room and causing waste of time and money. Aside from being able to detect unsound material, the etch test will also enable us to allocate the steel for various jobs. For instance, by means of this test, one can easily pick out a bar of steel with the best structure and chemical composition for the most intricate and expensive tools, and in this way one

eliminates good many blames which usually surrounds every one that has anything to do with a tool, and above all it means starting right from the beginning.

To sum up, the main problem connected with the tool steel with which the tool steel user has to contend with, is whether or not the steel that he is going to make up into tools is structurally sound and of right chemical composition. Deep etch test has been found of great value in the attempt to solve this problem. It should be, therefore, supported by every one concerned with the problem and the method should be developed and standardized as much as possible.

QUESTION NO. 64. To what extent can the deep etching of specimens of steel be applied to routine examination of incoming material?

ANSWER. By J. O. Liebig, metallurgist, Lancaster Steel Products Corp., Lancaster, Pa.

The deep etching of specimens on incoming material can be carried out very satisfactorily as routine in selecting 10 per cent of incoming material. I presume that incoming material, in this case, is meant hot-rolled or cold-drawn bars or wire.

A satisfactory etching solution to use is equal amounts of hydrochloric acid and water. The samples can be placed in large evaporating dishes and solution poured over the samples, making it possible for a great number of samples to be etched at one time.

A great many defects are brought out by deep etching, some of the most common being seams, pipes and non-metallic segregations.

In inspecting lots of steel received by etching should 10 per cent of the material be insufficient for proper check, further samples can be taken and a good idea obtained as to the acceptability of the material.

Of course, local conditions in the various plants determine to what extent the material should be sampled. It is more or less a matter of judgment.

QUESTION NO. 67. What is the reason for the fact that a piece of steel quenched in brine will be harder than the same piece of steel would be if quenched in water, providing that the quenching temperatures and quenching medium temperatures are the same in each case?

QUESTION NO. 69. Is sulphur up to .10 per cent detrimental to the quality and physical properties of an automotive steel?

QUESTION NO. 71. How do the physical properties compare between a 0.35-0.45 per cent carbon acid open-hearth steel and an alloy steel of either 3.5 per cent nickel or 1.5 per cent nickel and 0.50 per cent chromium neither heat treated?

QUESTION NO. 72. What elements are conducive to good electric butt-welding of steels?

QUESTION NO 73. Does electric butt-welding destroy the physical properties developed in a steel which has been heat treated prior to the welding operation?

QUESTION NO. 74. Why shouldn't a bar of steel rolled from a locomotive axle be better than one rolled direct from the billet made from the original ingot?

QUESTION NO. 76. Why are cold drawn carbon and high-speed steels sometimes supplied with a copper coating? Does this coating affect the steel in any way, or is it merely a lubricating agent in the drawing process? Is it necessary or desirable to remove the coating before hardening?

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

SERVICE FOR MEMBERS

The Library Bureau of the American Society for Steel Treating is operated to give to the members quickly, reliably and at the minimum expense the following service:

1. A complete copy of the magazine article referred to in any periodical you may be reading.
2. A translation of foreign articles that would help you with your work.
3. A list of references to books and articles on any metallurgical subject.
4. Informing the members of new articles of interest to them as an engineer.

The Library Bureau makes the entire field of literature available to every member, distance is eliminated, for it will copy the desired information and send it to you. It also helps the busy man by supplying information without any expenditure of his time. The charge for this personal work is merely its cost.

The Library Service does not obtain any profit from the work, but does this to make the information contained in the large libraries with which it has connection available to every member. The rates are as follows:

Photo Print Copies of articles, drawings, etc., 25c per 10 x 14-inch sheets.
Searches, abstracts, etc., $2.00 an hour.
Translations, $6.00 per thousand words for French or German; $7.50 and upward for other languages.
Reference card service, giving reference to current magazine articles, $10.00 a year in advance, and 5c for each card mailed.

Members desiring to avail themselves of this service should address Library Bureau, American Society for Steel Treating, 4600 Prospect Ave., Cleveland, Ohio.

USE OF LIQUID FUEL IN METALLURGICAL FURNACES. By R. C. Helm, in *Blast Furnace and Steel Plant,* page 549-546 (1922).

The above article gives the use of fuel oil and tar and also discusses the various types of burners used. It states that the successful use of fuel oil depends on furnace design, as well as proper methods of distribution and on burners which will thoroughly atomize the fuel. For further development mechanical injection of the oil and the use of the recuperative principle for the gas must be perfected. The discussion given deals principally with open-hearth furnaces and furnaces for the heat treatment of wire products.

HARDNESS AND HEAT TREATMENT OF MINING DRILL STEEL SHANKS. By C. Y. Clayton, in *Transactions* of American Institute of Mining and Metallurgical Engineers No. 1203 (1923).

The article states that the hardness of mining drill shanks varies between 196 and

782 Brinell, the greater number of steels showing values between 364 and 444. Methods of heat treating vary not only between different mines but also between operators. Water, oil and air are the quenching media used. The length of shank treated varies between ½ and 8 inches. The results show that if drill shanks are to give satisfactory service a standard method of heat treating must be adopted by each shop.

HEAT TREATMENT OF STEEL CASTINGS. By H. C. Ihsen, metallurgical engineer, Westinghouse Electric & Manufacturing Company, in *Forging and Heat Treating,* March, 1923, page 138-143.

In this articles the author discusses the characteristics of steel castings in the raw state as well as the heat treated condition. The correct treatment of these casings with reference to size and composition is also considered.

A NEW FORM OF TEST BAR FOR THE NOTCHED-BAR SHOCK TEST. By Messrs. Saniter and Baker, in *Revue de Metallurgie,* No. 19, page 633 (1922).

This article says that according to Hadfield, low-carbon steels can be classified as either ductile or brittle, depending on the rate of the shock, while according to Stanton contradictory results can be obtained with the same steel depending on the section of the test-bar. In mild steels the shape of the bar in use at the present time involves considerable deformation and incomplete rupture. In order to overcome these drawbacks, the authors devised a bar notched on three sides, having the same useful cross-section as the usual bar. The same thickness and notch were used as on the standard British Engineering association bar, but the width was increased to allow for the two side notches. Tests were carried out with a Charpy pendulum. The results showed that the deformation of the broken bars was reduced to a minimum, and that the energy absorbed was lower than that in the standard test. In steels with high brittleness, the brittleness found was higher with thick bars than with thin ones, and similarly with low brittleness, consequently this explains why comparable results cannot be obtained with bars of different dimensions.

HOT WORKING OF METALS. By R. Genders, in *Bulletin* of British Non-Ferrous Metals Research Association, No. 7, page 7 (1922).

The author in this article states that hot-working may be defined as a mechanical treatment at a temperature above that at which recrystallization takes place rapidly. The proper working temperatures of a number of brasses are given, and the extrusion process is discussed.

OBSERVATIONS ON THE CONSTRUCTION AND INSTALLATION OF HYDRAULIC FORGING PRESSES. By W. R. Ward, consulting engineer, Lyells, Virginia, in *Forging and Heat Treating,* March, 1923, page 143-146.

In the above article is given a description of the manufacture of forging presses as well as various operations and materials.

CORROSION OF IRON. By J. N. Friend, in Iron and Steel Institute, page 156 (1922).

In this article the author gives a survey of the present knowledge of the corrosion of cast iron and steel. A method is also given whereby the life of the metal may be prolonged.

LINING ACID ELECTRIC FURNACES. By J. M. Quinn, U. S. High-Speed Steel & Tool Corp., in *Iron Age,* April 19, 1923, page 1101.

The author gives the various materials which can be used and the method of handling them. The best lining is also described.

THE METALLURGY OF SEMI-STEEL. By David McLain, in *Forging and Heat Treating,* March, 1923, page 151.

The above is a lecture that was delivered before the British Foundrymen's Convention in Birmingham, England, June, 1922 and deals with historical facts concerning the development of semi-steel.

THE CRYSTALLOGRAPHY OF CEMENTITE. By N. T. Belaiev, in *Revue de Metallurgie,* page 573 (1922).

In this article the subject is discussed in detail and is illustrated with five photomographs.

PREPARATION AND PROPERTIES OF PURE IRON ALLOYS. EFFECTS OF CARBON AND MANGANESE ON THE MECHANICAL PROPERTIES OF PURE IRON. By R. P. Neville and J. R. Cain, in *Scientific* Papers of Bureau of Standard, No. 453.

More than one hundred alloys were prepared from purified iron, carbon and manganese, and the compositions were chosen as to bring out the effects of carbon and manganese on pure iron.

SPECIFICATIONS FOR STEEL CASTINGS FOR RAILROADS. By F. M. Waring, in *Proceedings* of American Society for Testing Materials, No. 22, page (1922).

The sulphur and phosphorus limits are set at 0.05 and manganese at 0.85 per cent and the physical properties are discussed.

SELECTION OF STEEL FOR COLD FORGING. By John B. Frederick, in *Forging and Heat Treating,* March, 1923, page 161.

This article discusses the materials best fitted for cold forging operations. It gives the cause of woody fractures of cold headed cap screws and states that annealing may be used to remedy this condition..

CUPOLA MALLEABLE PRODUCTION. By C. C. Hermann, in *Foundry* #50, (1922).

This article states that in manufacturing malleable iron, the cupola process is the cheapest and most economical, and discusses the various kinds of scrap used.

CONVERTER MAKES BETTER STEEL. By R. Burke, in *Foundry* #50, page 915, (1922).

This article states that the purity of the material and the absence of oxides in the finished blow are depended upon for the successful operation of the converter.

MANUFACTURE OF ALLOY STEEL FOR AIRPLANE SHAFTS. By E. Kothny, in *Chemical and Metallurgical Engineering,* #27, page 1020, (1922).

This article gives an explanation of the manufacture of nichrome steel in the Heroult furnace, and also gives a method of manufacturing alloy steel for airplane shafts. It further states that it is important that very good raw material be used.

CUTTING METALS WITH THE ELECTRIC ARC. By A. M. Candy, Westinghouse Electric & Manufacturing Company, in *Iron Age,* April 19, 1923, page 1098.

In this article the author gives the hourly rate and the cost of cutting the metals. The use of various methods for scrapping discarded steel freight cars is discussed.

Reviews of Recent Patents

1,439,454. Art of Treating Castings. W. Y. Stroh, Pittsburgh, Pa., and J. Thompson, Oakmont, Pa., assignors to Catherine Strayer, Pittsburgh, Pa.

This patent covers an article of manufacture, a casting having a finished and polished surface produced directly upon the surface of the casting solely by the action of a series of hammer blows.

1,439,972. Electric Arc Welding. P. O. Noble, Schenectady, N. Y., assignor to General Electric Co., a corporation of N. Y.

An arc welding machine employing a fusible electrode, the combination with means adapted to feed the electrode to the work to be welded, and a means for conducting a fusing current to the electrode, and a means for applying a coating or covering of liquid material to the electrode as the latter is fed to the work to be welded.

1,439,865. Nickel Alloy. Leon Cammer, N. Y. C., assignor to the International Nickel Co., a corporation of N. J.

This patent comprises an alloy of nickel, copper and aluminum, wherein the content of nickel is in excess of 50 per cent and the content of aluminum is not less than about 3 per cent and not more than 17 per cent, the predominant metal of the remaining content being copper.

1,440,470. Method and Apparatus for Testing Welds. Isaac F. Kinnard, Wilkinsburg, Pa., assignor to Westinghouse Elec. & Mfg. Co., a corporation of Pennsylvania.

This invention relates to a method of testing welds which comprises passing electrical energy through a weld to be tested and comparing the character of the energy passing through the weld to that passing through the body of the material.

1,440,724. Electrode for Electric Furnaces and Process for Manufacturing the Same. Carl Wilhelm Soderberg, Christiania, Norway, assignor to Det Norske, Aktieselskab for Elektokemisk Industri, Chistiania, Norway.

This relates to a process of manufacturing electrodes for electric furnaces, which comprises tamping raw electrode mass into a metallic mantle constituting a part of the electrode and which is provided with projections extending into the electrode mass, and passing electric current through the mantle whereby heat is generated and distributed into the interior of the electrode mass and baking the latter is thus effected.

1,440,546. Furnace. Frederick C. Langenberg, Watertown, Mass., and John F. Fetterly, Altoona, Pa., assignors to the Surface Combustion Co., Inc., New York city a corporation of New York.

This invention refers to a furnace which is composed of a heating chamber, a diaphragm extending inwardly from the wall of said chamber and having an inner edge adapted to extend close to the surface of the object to be treated, and means for supplying heat to the zones formed in said chamber by said diaphragm, whereby a desired temperature may be maintained in each zone.

1,440,446. Furnace Roof. Walter H. Cotton, Chicago, Ill.

This relates to a furnace roof which comprises a course of brick consisting of a plurality of independent abutting sections, each section being composed of a plurality of interlocking brick and a supporting hanger for each section.

1,440,468. Sectional Furnace Roof. Abraham L. Kanagy and Walter H. Cotton, Chicago, Ill.

This refers to a sectional furnace roof which is composed of a plurality of sections each consisting of a pair of beams having projecting ledges, a plurality of brick having projections complementary to and resting on said ledges, and means for holding the beams in parallel relation.

1,440,540. Method of and Apparatus for Heat Treatment. William J. Harris, Jr., New York city, assignor to the Surface Combustion Co., Inc., a corporation of New York.

This invention relates to a method of heat treatment as well as an apparatus for the same. The method consists of heating different zones of an article under treatment to different temperatures while securing a uniform heating around the periphery of each zone of the article, which surrounds the article with a body of gases, causing said body of gas to whirl about the article in planes perpendicular to the axis of the article, and maintaining the gases whirling about one zone of the article at a temperature different from the gases whirling about another zone of the article.

The apparatus is composed of an outer cylindrical wall, an inner wall into an annular combustion chamber and a cylindrical treating chamber, and means for causing combustion in said combustion chamber and for causing a whirling of the burning gases in said combustion chamber, said inner wall being provided with passages adapted to direct the whirling gases from the combustion chamber into the heating chamber and cause them to continue their whirling motion in the treating chamber.

1,440,619. Process of Cleaning and Surfacing Sheet Steel. Samuel M. Noyes and Samuel Peacock, Wheeling, W. Va.

This refers to a process of cleaning and surfacing sheet steel containing cementite and ferrite in its surface which consists in mechanically removing said cementite leaving channels in the ferrite; and mechanically spreading said ferrite over said surface to fill said channels and inhibit the subsequent oxidation of said surface, substantially as described.

1,440,657. Highly-refractory Article and Method of Producing the Same. Henry H. Buckman, Jacksonville, Fla., and George A. Pritchard, New York city, assignors to Buckman & Pritchard, Inc., Jacksonville, Fla., a corporation of Florida.

This patent describes a new article of manufacture which is a highly refractory material containing zirconia and also silica.

1,441,479. Process for Making an Alloying Alloy. Wilson Bennett, Wellington, New Zealand.

This invention relates to a process of producing an alloying alloy which consists in mixing chromium ores with ore reducing agents in an electric furnace, passing an electric arc through the mixture to reduce and refine the metals, removing the resulting slag, adding a decarburizing mixture including a high content of silicon to the remaining metals and passing a current through the mass to reduce the carbon to a low percentage and to eliminate excessive chromide oxide losses during the decarbonization, and removing the resulting slag.

1,442,444. Casting High-melting-point Metal. Howard T. Reeve, East Orange, N. J., assignor to Western Electric Co., Inc., New York city, a corporation of New York.

This refers to a method of obtaining high melting point metals and alloys in the form of rods of small diameter which consists in forcing the molten material into a tube of refractory material, allowing it to cool therein and separating the material from said tube.

News of the Chapters

SCHEDULED REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Boston—Second Tuesday
Bridgeport—Thursday between 20th and end of month
Chicago—Second Thursday
Cincinnati—Second Thursday
Cleveland—Fourth Friday, Cleveland Engineering Society Rooms, Hotel Winton; meeting at 8:00 p. m.
Detroit—Second and fourth Monday, Wing E., 15th Floor General Motors building.
Hartford—Friday nearest 10th of month
Indianapolis—Second Monday
Lehigh Valley—No regular night
New Haven—Third Friday
New York—Third Wednesday
Philadelphia—Last Friday
Pittsburgh—First Tuesday
Providence—No regular night.
Schenectady—Third Tuesday
Springfield—Third Friday
South Bend—Second Wednesday
St. Louis—Third Monday
Syracuse—No regular night
Tri City—Thursday
Washington—Third Friday
Rockford—Second Friday following the second Thursday

MEMBERSHIP AND ATTENDANCE CONTEST

While last month it was observed that four chapters had an increase of over 50 per cent in membership, there are six chapters for the present month that are above the half-hundred mark. In fact, three of them have very nearly doubled in membership. However, this percentage does not represent all new members but also represents the bonus received for new sustaining members.

It will be observed that Cincinnati jumped from eleventh to third place. This is due largely to the fact that Dr. J. Culver Hartzell, the chairman, went out personally and single-handed, obtained ten new sustaining memberships, returning the same to this office with his check for $250.00. In this connection

it is interesting to note that the National Office returned to the Cincinnati Chapter $187.50 of this amount.

The following arrangement of the chapters shows the percentage of net increase of new members as of April, 1923, based on the number of members each chapter had on September 1, 1922.

	Per Cent		Per Cent		Per Cent
1. Tri City	98.8	10. Syracuse	38.2	19. Indianapolis	17.8
2. South Bend	92.0	11. Lehigh Valley	36.1	20. Washington	17.5
3. Cincinnati	83.2	12. Schenectady	29.4	21. Chicago	16.4
4. Detroit	67.6	13. Hartford	22.8	22. Pittsburgh	14.0
5. North West	54.3	14. Buffalo	22.5	23. St. Louis	10.5
6. Philadelphia	50.6	15. Cleveland	22.1	24. Springfield	10.3
7. New Haven	42.5	16. New York	21.6	25. Worcester	8.9
8. Milwaukee	42.2	17. Toronto	21.4	26. Providence	5.3
9. Boston	40.9	18. Rockford	18.7	27. Rochester	4.8

Attendance at March Meetings

Only 16 chapters reported attendance at March meetings. There are other chapter meetings, reports of which did not reach the office that were held late in the month. No attendance report was received from the following chapters: Boston, Buffalo, Chicago, Hartford, Indianapolis, Lehigh Valley, Rochester, Schenectady, Toronto, Washington and Worcester.

The following gives the percentage of attendance at March meetings. Those chapters printed in CAPS show an increase in percentage of attendance over that of the February meeting:

	Per Cent		Per Cent		Per Cent
1. NEW HAVEN	69.7	7. ST. LOUIS	38.5	13. Milwaukee	26.0
2. SOUTH BEND	69.2	8. DETROIT	35.1	14. Cleveland	21.6
3. TRI CITY	60.7	9. CINCINNATI	31.8	15. Pittsburgh	14.6
4. Providence	45.7	10. North West	30.0	16. New York	11.2
5. Syracuse	44.8	11. Philadelphia	29.0		
6. SPRINGFIELD	38.9	12. Rockford	27.5		

Standing of the Chapters in Contest

In order to determine the standing of each chapter in the contest it is necessary to add the percentage of attendance at the December, January, February and March meetings and divide by four to determine the average attendance for the four meetings. The average thus obtained is added to the percentage of net increase obtained since Sept. 1, 1922 to March 31, 1923. This total is then divided by two to obtain the standing of each chapter in the contest inasmuch as attendance counts 50 per cent and increase in membership 50 per cent.

On this basis we find the following to be the standing of the chapters on April 1, 1923, in the Membership and Attendance contest:

	Per Cent		Per Cent		Per Cent
1. Tri City	74.3	8. Philadelphia	41.1	15. Washington	24.4
2. South Bend	73.8	9. Milwaukee	35.9	16. Springfield	23.1
3. Cincinnati	53.7	10. Boston	32.8	17. Cleveland	22.3
4. New Haven	47.5	11. Providence	31.0	18. Chicago	18.7
5. Detroit	46.9	12. Rockford	29.2	19. New York	18.7
6. North West	46.1	13. Hartford	28.2	20. Indianapolis	17.8
7. Syracuse	43.5	14. St. Louis	28.0	21. Pittsburgh	14.9

In this connection it is interesting to note that there are two new faces among the leaders—Cincinnati and New Haven. Cincinnati jumped

from the fourteenth place in the contest to the third, and New Haven from ninth to fourth. The contest for first place is still quite sharp between Tri City and South Bend and reverses the standing as of February when South Bend was first and Tri City second.

There is no reason whatever for any of the other chapters becoming discouraged—as an example, the advancement of Cincinnati is possible for one chapter as well as for another. The only thing required is a little time and the selection of the proper individuals to call upon the manufacturing firms in your territory and secure from them the co-operation your chapter deserves.

Based on the number of members in each chapter on April 1, 1923, the following table shows the standing of the twenty-seven chapters of the Society. Those printed in CAPS have advanced their position while those that are in *italics* have a lower position than that occupied in the previous report:

1. Detroit
2. Chicago
3. PHILADELPHIA
4. *Pittsburgh*
5. Cleveland
6. New York
7. Hartford
8. MILWAUKEE
9. *Boston*
10. *Syracuse
11. *Lehigh Valley
12. *North West
13. *Tri City
14. *Worcester
15. *CINCINNATI
16. **St. Louis*
17. **Indianapolis*
18. *Rockford*
19. SOUTH BEND
20. *Washington*
21. *Buffalo*
22. NEW HAVEN
23. **Schenectady*
24. *Providence
25. *Springfield*
26. Toronto
27. Rochester

*Tied

MEETING AT MUNCIE, INDIANA

Marcus A. Grossmann, chief metallurgist with the Atlas Steel Corporation, Dunkirk, N. Y., addressed over three hundred men interested in iron and steel at a meeting held in the main auditorium of the Central high school at Muncie, Ind., on Monday evening, April 16.

The address was given under the auspices of the department of industrial education in charge of Glen D. Brown, director.

The Muncie city schools are indeed fortunate in having such an adequate and complete industrial department and has for some time maintained an enviable reputation among high schools of the country for the wonderful co-operation it has given in catering to the needs of the industries of their vicinity, consequently it was not unusual that they should have this meeting of men interested in iron and steel due to the fact that over forty-four industries in their thriving business district are engaged in the fabrication of steel.

The close proximity of the cities of Anderson and Newcastle to Muncie makes the territory all the more vitally interested in the subject Mr. Grossmann discussed and all of these influences increased the attendance at the meeting.

The meeting was opened by Director Brown, acting as temporary chairman, who turned the meeting over to W. H. Lyman, superintendent of the Warner Gear Company, of Muncie.

Mr. Lyman outlined briefly the work of the industrial department of the high school and congratulated those present upon the high caliber of the work carried on and the wonderful aid that the department was to the local industries.

Mr. Lyman introduced Vere Sutton, superintendent of the Muncie Prod-

ucts division, General Motors Corporation, Muncie, who acted as permanent chairman and introduced the speaker of the evening.

The subject of Mr. Grossmann's talk was "The Electric Furnace and Crucible Practices in the Manufacture of Steel." He handled the subject in a very interesting and entertaining manner, illustrating many of the important operations with moving pictures.

At the close of Mr. Grossman's remarks, W. H. Eisenman, national secretary of the A. S. S. T., was introduced and outlined briefly the aims and accomplishments of the society.

Mr. Sutton made the statement that the cities of Anderson, Newcastle and Muncie might consider seriously the organization of a chapter of the A. S. S. T. in case there was sufficient interest manifested by the manufacturers and interested men in that locality.

A number of other gentlemen representing various cities and industries discussed the advisability of the establishment of a local chapter at this time and then upon motion duly made and seconded it was decreed that Mr. Sutton should appoint a committee to thoroughly canvas the situation and to report at a future meeting as to the advisability of organizing a chapter in that territory to include the cities of Muncie, Anderson and Newcastle.

BOSTON CHAPTER

The Boston chapter of the American Society for Steel Treating held its regular monthly meeting on April 18, at 3 p. m. at the plant of the Waltham Watch Company, Waltham, Mass.

The program for this meeting was a trip through the plant of the Waltham Watch Company. Following the inspection of the plant members and guests assembled at the Adams House, Waltham, where an informal dinner was served at 6:30 p. m.

Following the dinner the meeting adjourned to the Riverside club of the Waltham Watch Company for a social hour, at which time A. J. Erickson, foreman of the machine shop, presented a paper entitled "Heat Treating Problems in Watch Making."

Mr. Erickson brought out many points pertaining to the heat treatment of small parts for watches, especially that of springs.

Following this paper the motion picture entitled "The Story of Alloy Steel," which was produced by the United States bureau of mines, was exhibited.

This meeting proved to be highly successful and of extreme interest to all who had the privilege of attending.

BUFFALO MEETING

The Buffalo chapter of the American Society for Steel Treating held its regular monthly meeting on April 24, at 8:00 p. m., in the Hotel Statler.

The Buffalo chapter was very fortunate in obtaining as speaker for this meeting, C. G. Armstrong, of Chicago, who presented an interesting and worthy paper entitled, "Steel Treating Furnaces."

Mr. Armstrong reviewed with considerable detail the various designs of steel treating furnaces and their application to the various types of treating.

He discussed the various types of fuels that are used in the heat treatment of steel, bringing out many points of information relative to the efficiencies and adaptability of many fuels available.

The subject of furnaces and refractories has always been a matter of keen interest to steel treaters, inasmuch as good uniform treatment can only be accomplished through the uniform application of heat to the parts and in turn this uniform application can only be accomplished through the proper design and construction of the furnaces combined with the proper type of burners and the proper type of fuel.

Following the presentation of this paper a long and interesting discussion was held on the subject of furnaces and fuels.

The meeting was well attended by many of the members of the Buffalo chapter and their guests.

At 6:30 p. m., the usual get-together dinner was served to a good sized number of members and guests.

All in all this meeting was a very successful one.

CHICAGO CHAPTER

The regular April monthly meeting of the Chicago chapter was held at the City club, 315 Plymouth court, on the twelfth of April, 1923.

The usual get-together dinner was served at 6:30 p. m. and the regular meeting followed at 8 p. m.

The Chicago chapter was favored by a very interesting paper presented by O. T. Muehlemeyer, metallurgist of the Barber Colman Co., Rockford, Ill., on the subject of "Hardening Room Practice."

Mr. Muehlemeyer, who is a very capable metallurgist, having successfully operated some of the largest heat-treating plants in this country, presented some very interesting and valuable data in reference to his subject.

Following the presentation of this paper, a very interesting and helpful discussion ensued.

The Chicago chapter had a very large turnout for this meeting, which proved to be a decided success.

CINCINNATI CHAPTER

On Thursday evening, April 12, the Cincinnati chapter of the American Society for Steel Treating, held its regular monthly meeting at the Ohio Mechanics institute, Canal and Walnut streets.

The chapter was very fortunate in having as their speaker Major F. F. McIntosh, professor of metallurgy at the Carnegie Institute of Technology, Pittsburgh, Pa., who presented a very capable paper entitled "The Application of Alternating Stress Tests to Industrial Problems."

In addition to his affiliation with the Carnegie Institute of Technology, he is consulting metallurgist for several of the largest Pittsburgh steel companies and other Pittsburgh corporations. During the war Major McIntosh was in the inspection division of the ordnance department and did much very valuable work. He has had many years' experience in the testing and inspection of steel and steel products, and as a result presented some very interesting information for both practical and technical men.

CLEVELAND CHAPTER

The Cleveland chapter of the American Society for Steel Treating

held its regular April monthly meeting Friday evening, April 27, at 8:00 p. m., in the Cleveland Engineering society rooms, Hotel Winton.

The program for this meeting was a paper by Dr. Paul D. Merica, director of research of the International Nickel Co., New York City, entitled "Nickel, Its Metallurgy and Uses."

Dr. Merica, who is a nationally known metallurgist in this country, formerly associated with the United States bureau of standards, has done a vast amount of work on metallurgical subjects, both ferrous and non-ferrous. His experience has been very broad, both along research lines and practical lines and as a result his paper was very interesting both to the technical man and the shop man.

He reviewed in considerable detail the properties of nickel and its application to the many phases of the industry, both as pure metallic nickel and as it is alloyed with other elements.

The paper was illustrated with stereopticon slides and proved to be very interesting.

A lively and interesting discussion followed Dr. Merica's presentation.

A very large turn-out of Cleveland members and guests was had at this meeting.

The usual get-together dinner was served at 6:30 p. m.

DETROIT CHAPTER

The Detroit chapter of the American Society for Steel Treating held its first meeting for the month of April, Monday evening, the ninth, at 8 p. m. in the east wing of the fifteenth floor of the General Motors building, Detroit, Mich.

The speaker for this meeting was H. F. Wood of the Ingalls-Shepherd division of the Wyman-Gordon Company, Harvey, Ill., who presented a very capable paper entitled "Management of Heat Treating Departments and Determination of Heat Treating Costs."

For a number of years back Mr. Wood has been intensively studying the items of cost in respect to the heat treatment of steels, and he presented a very capable paper on this subject, discussing many of the points which ordinarily are more or less difficult to determine. The problem of determining costs involves a wide range of items and it is only through careful study and collection of data that accurate costs can be ascertained. Determining overhead charges and depreciation have always caused a great deal of trouble in arriving at proper and correct costs. Mr. Wood developed a very logical plan for handling these two items of cost finding.

Inasmuch as Mr. Wood's company is devoted entirely to the forging and heat treating of materials on a large scale they have been able to make exhaustive tests and investigations to determine their thermal and power efficiencies.

Following the presentation of Mr. Wood's paper a very interesting and lively discussion ensued.

On Monday, April 23, the Detroit chapter held its second monthly

meeting for the month of April in the east wing of the fifteenth floor of the General Motors Company.

This meeting, as in the case of the former meeting, was preceded by the regular get-together dinner which was served at 6:30 p. m. in the meeting room.

The speaker for this second monthly meeting was H. G. Peebles, metallurgist of the Detroit Steel Products Company, who presented an illustrated paper entitled "The Manufacture and Inspection of Springs."

Mr. Peebles has had many years' experience in the manufacture and inspection of springs and presented a very capable and interesting paper.

Mr. Peebles handled his subject in a very capable manner and an interesting and profitable discussion followed its presentation.

Both of these April meetings were very well attended.

HARTFORD CHAPTER

The Hartford chapter of the American Society for Steel Treating held its regular monthly meeting on Friday evening, April 13, at 7:45 in the assembly hall of the Hartford Electric Light Company, Pearl street, Hartford, Conn.

Two speakers were scheduled to address this meeting. They were J. H. Coffey and C. M. Blackman.

Mr. Coffey presented many of his experiences during a half century of service in the forging and heat-treating departments of the Pratt & Whitney Company, and Mr. Blackman related some of the things that make life interesting for him in the heat-treatment room of the Colt Manufacturing Company.

Both of these gentlemen related many of the interesting problems that they have encountered and the manner in which they were solved.

Following the two talks the following questions were presented for discussion. These questions had been included on the regular announcement of the meeting, so that all members had the opportunity of reviewing them prior to the meeting with the result that a great many valuable points of information were developed.

1. In quenching steel does it expand or contract? What are the conditions governing its action?
2. What are the causes, and what are the best conditions for shrinking holes in tool steel?
3. How may warpage be overcome in long slender tools? Are quenching fixtures applicable to such work?
4. What is the best method of preventing cracking through holes in blanking dies, etc?
5. Which quenching medium will produce the greatest depth of hardening and the greatest hardness, oil, water, or brine?
6. Can high carbon chrome ball steel be quenched from 1650 degrees Fahr. into brine without cracking?
7. What is the result of the following treatment? Heat ball steel to 1500 degrees Fahr., remove and place in another furnace at 1250 degrees Fahr., cool to furnace temperature, then quench.
8. What is the best method of preventing carburization in holes, or in the bore of parts to be case hardened?
9. Can satisfactory cutting tools be made by case hardening soft steel?
10. What are the requirements for a good spindle, hardness, etc? How obtained?
11. Burnishing tools—Why do some burnishing tools used in the silver

industry "pick up" emery, while others, apparently the same, do not?
12. What is the best way to harden "non-shrinking" tool steel?
13. What are the relative importance of "brand" and "composition" in the purchase of tool steel?
14. Can cracks be produced in sound hardened steel by grinding? Can hardened steel be softened by the grinding operation?
15. What causes black fractures in tool steel?
16. Which furnaces are most economical for heat treatment, over-fired or under-fired?
17. Are electric furnaces suitable for heat treatment where freedom from scale is an important factor?
18. Can a reducing atmosphere in a furnace cause decarburization and result in softness after quenching?
19. What is the value of the deep etch, and what are its shortcomings?

This meeting proved to be highly successful and much valuable information was disclosed.

The usual informal get-together dinner was served at the Bond hotel at 6:30 p. m., preceding the meeting.

INDIANAPOLIS MEETING

The Indianapolis chapter staged one of its old-fashioned, good-natured, well-attended chapter meetings at the Missouri Athletic club on Tuesday evening, April 17, when Marcus A. Grossmann, chief metallurgist with the Atlas Steel Corporation, Dunkirk, N. Y., and national secretary, W. H. Eisenman, were present.

Over one hundred members were in attendance to hear Mr. Grossmann, who gave a very interesting and detailed description of the processes of making steel by the use of the crucible and electric process.

Mr. Grossmann is an authority on the manufacture of steel and the freedom with which he spoke on mill practices and the reasons for various operations proved to be quite interesting and highly educational.

Quite a lively discussion took place upon the completion of Mr. Grossmann's paper and was entered into with a hearty spirit and was highly satisfactory.

Chairman Deeds then introduced the national secretary, who outlined briefly the accomplishments and the ambitions of the A. S. S. T. as well as reporting the progress the society made last year.

The nominating committee made their report of officers to be elected at the May meeting and after various other committee reports and matters of general interest a buffet luncheon was served by the Athletic club. This luncheon was quite a factor in adding to an already enjoyable and pleasant social evening.

EDUCATIONAL COURSE AT INDIANAPOLIS

The Indianapolis chapter has every reason to be proud of the very successful results that have been accomplished by the course conducted by the chapter at the Manual Training high school in Indianapolis.

For some time there has apparently been a demand on the part of the industries in the vicinity for some course dealing with the fundamentals of metallurgy to which those who aspired to a greater understanding of the processes of science might have an opportunity to acquire this information.

In order to meet this demand the local chapter under the chairmanship of Mr. Deeds rose splendidly to the occasion and early in the fall got to-

gether one hundred and fifty members of the chapter and men in the manufacturing industries of the city, at which meeting the general problems and conditions of the course were investigated.

It was learned that the facilities of the Manual Training high school would be available for the use of the class through the courtesy of their efficient principal, Mr. McComb.

In order that any course on the fundamentals of metallurgy may be a success it is necessary that it should have a director invested with the sole responsibility and the selection of this individual was the next problem that confronted the chapter. However, the chapter had little difficulty in solving this momentous problem due to the presence in their organization of H. B. Northrup, chief metallurgist of the Diamond Chain Company and vice-chairman of the Indianapolis chapter.

Mr. Northrup was for a number of years engaged in the teaching of metallurgy at Penn State college, and besides his valuable experience in war work, had had an extensive practice in the practical side of metallurgy.

Mr. Northrup kindly consented to undertake the work of the preparation and shaping up of this course and the chapter set about to secure the enrollment of the proper number of individuals. A letter was prepared and sent out to all manufacturing firms informing them of the approaching course and suggesting that inasmuch as thousands of dollars were lost each year due to faulty heat treatment that they should be particularly interested in having their men enroll as members of this course.

The manufacturing industries of Indianapolis responded splendidly to this notice and many of them even went so far as to state that in case the men in their employ should enroll in the course and pay the charge of $6.00, they would be pleased to reimburse their employes provided they attended 75 per cent of the lectures.

Consequently, on December 8, the first organization meeting of the night course was held and sixty men enrolled to take the course of fifteen weeks.

It was decided to hold the meetings regularly each week on Monday evening and the regular course began immediately after the holidays and has continued successfully through to the present time with but two more lectures to be held.

As previously stated, the lectures are held at the Manual Training high school and the equipment used in the course has been furnished by the local industries; the furnace having been donated by the Imperial Drop Forge Co. The lectures are held in the evening and are of two hours duration, starting at 7:30 and closing at 9:30 p. m.

One of the most remarkable instances in connection wth this course has been the constant attendance, which has been due to several reasons, probably the most important of which is the able direction of the director of the course in making his lectures and those who contributed special lectures of such interest and upon such vital subjects that the men have developed a decided interest in the lectures and are conscious of the benefits they are able to obtain.

The greater number of lectures have been delivered by principal Northrup, although G. F. Atkins, of the E. C. Atkins & Co., delivered one lecture on the subject of "Quenching in the Hardening Range," while H. W. Hayward of the Link-Belt Co., gave a paper and demonstration on the subject of "Testing For Physical Properties." The class was taken to the Link-

Belt physical laboratories where Mr. Hayward demonstrated the uses of various testing apparatus.

Paul Deeds, metallurgist at the Indianapolis Tool and Manufacturing Co., gave a very interesting and instructive lecture on "Carburizing Practices," while Professor John Keller, head of the extension department of Purdue university, gave a lecture on "Why Steel Warps," and also "The Selection of Steel by Means of the Spark Test." The lecture by Mr. Grossmann before the regular meeting of the chapter also served as supplementary information to the members of the class on the manufacture of steel by the crucible and electric process.

The general outline of the lectures in the course in metallurgy presented by Mr. Northrup, is as follows:

I. Historical. Outline of the development of the iron and steel industry.

II. Iron Ores. A study of the principal ores of iron with especial reference to the metals and metalloids which are inherent in the ore and traceable directly into the finished product.

III. The Iron Blast Furnace. A study of the evolution of the present day furnace and the effect of furnace design upon the quality and quantity of the resultant metal.

IV. Blast Furnace Fuels, Fluxes and Refractories.

V. Modern American Blast Furnace Practice.

VI. Effect and Control of the Elements Entering Into Pig Iron.

VII. The Manufacture and Some of the Uses of Wrought Iron and Crucible Steel.

VIII. Bessemer Steel, Its Manufacture and Adaptability.

IX. Open Hearth Steel. Methods of manufacture and some of its commercial applications.

X. Definitions and Terms. Cast iron. Pig iron. Gray cast iron. White cast iron. Malleable cast iron. Steel. Wrought iron. Ferrite. Cementite. Pearlite. Sorbite. Troostite. Martensite. Austentite. Normalizing and Normal Structure. Annealing and Annealed Structure.

XI. Effects of the Added Elements on Steel. Effects on its physical properties and upon the thermal critical points as effecting heat treating.

XII. Heat Treatment. The Iron-Carbon diagram. Causes of the thermal critical points in iron and steel. Changes which take place at the various critical points.

XIII. Temperature Measurement. Instruments used, their application and calibration.

XIV. Carburizing. Materials used and their selection. Carburizing practice.

XV. Physical Testing. Machines and methods used. Definitions and terms used. Explanation of the correlation between heat treatment and physical properties.

The results of the course this year have been so satisfactory that there is a demand that the course be repeated next year and it is probable that this will be done.

One of the most encouraging features of the entire work has been that the attendance at the meetings has been 75 per cent of the enrollment.

The Indianapolis chapter, both collectively and individually, and especially

those who have been directly in charge of this work, have contributed a very valuable piece of work to the industries served by the local chapter and their record will be one that will be looked upon as a wonderful service by the American Society for Steel Treating to the industries it serves.

LEHIGH VALLEY CHAPTER

On Friday evening, April 27, at 8 p. m., the Lehigh Valley chapter of the American Society for Steel Treating held a meeting at the Engineers' club, Reading, Pa., at which time F. O. Kichline, engineer of tests at the Bethlehem Steel Company's Lebanon plant presented a paper entitled "The History of the Iron and Steel Industry in Eastern Pennsylvania."

Mr. Kichline's presentation was very interesting, and especially so to the members of the Lehigh Valley chapter, inasmuch as his paper covered much of the history in the immediate vicinity of Bethlehem and Reading.

This meeting was well attended and proved to be a decided success.

MILWAUKEE CHAPTER

The Milwaukee Chapter of the American Society for Steel Treating held its regular April monthly meeting Tuesday evening, April 17th, at 8:00 p. m., at the Blatz Hotel, East Water and Oneida Streets, Milwaukee, Wis.

The speaker for this meeting was Jerry Burns, of the E. F. Houghton & Co., who presented a paper entitled "Quenching Media." Much valuable information was disclosed by Mr. Burns in his paper and the members of the Milwaukee Chapter felt fully repaid for their attendance at this meeting.

The selection of the proper quenching medium is a very vital factor in the proper heat treatment of steels and one which deserves more attention than it has had in the past.

This meeting was especially well attended and as evidenced by the large amount of interesting discussion which followed the presentation of the paper of the evening, the meeting was a decided success.

NEW HAVEN CHAPTER

The New Haven chapter of the American Society for Steel Treating held a meeting on Friday evening, April 20, 1923, at 8 p. m. in the assembly room of the New Haven Gas Light Company, 70 Crown street, New Haven, Conn.

Dr. Paul D. Merica, metallurgist with the International Nickel Company, was the speaker for this meeting. The subject of his paper was "The Metallurgy and Uses of Nickel and Nickel Alloys."

Dr. Merica, formerly with the U. S. bureau of standards, has done a vast amount of metallurgical work and is an authority on the subject of alloy steels, especially those of nickel.

Dr. Merica presented his paper in a very capable manner and brought forth many valuable points of interest and information.

Following the presentation of his paper a very valuable and interesting discussion ensued.

This meeting was very well attended and proved to be a decided success.

NEW YORK CHAPTER

The New York chapter of the American Society for Steel Treating held its regular April meeting on Wednesday evening, the eighteenth, at 8:15 p. m. in the assembly room of the Merchants Association of New York, ninth floor, Woolworth building, New York city.

The program for this meeting was a paper by C. H. Wilson, of the Wilson-Maeulen Company, entitled "Some Practical Considerations in the Use of Pyrometer Thermocouples."

Mr. Wilson illustrated his paper by means of blackboard sketches and brought out many points with reference to pyrometers, and pyrometer thermocouples and apparatus used in the determination of temperature in the heat treatment of steels.

Mr. Wilson developed his subject in a very interesting and entertaining manner and brought out many points that clarified some of the misunderstandings and misconceptions in the use of thermoelectric heat measuring devices.

Following the paper a general round-table discussion on pyrometry was held, with the general consideration of such questions as "What is the matter with my pyrometers?" This discussion brought out many interesting points and was participated in by a large number of the members of the New York chapter.

The meeting proved to be highly successful and of benefit to all.

The usual get-together dinner was served at 6:30 p. m. at the Post Keller restaurant of the Woolworth building.

NORTH WEST CHAPTER

At the meeting of the North West chapter Wednesday evening, March 28, William I. Sweet, of the Auto Engine Works, St. Paul, spoke upon the "Heat Treatment of Certain Motor Parts." He discussed the best methods of hardening pistons, crankshafts, connecting rods, piston wrist-pins, camshafts, valve tappets, main bearing-bolts, connecting rod-bolts, clutch cones, various gears and steel casting parts.

Mr. Sweet also demonstrated the spark test for identifying different grades of steel, which was illustrated by low carbon steel, medium carbon steel, high carbon steel, different kinds of alloy steels, and cast iron.

The talk was well received and brought forth considerable discussion. The members felt that they could make practical application of the spark test in their plant practice for identification of different kinds of steel.

Mimeographed briefs covering Mr. Sweet's presentation of the subject were dstributed to all members present so that they might have a permanent record of what is considered and recognized as standard practice for the heat treatment of certain parts. Blue prints together with descriptive material of the spark tests were also distributed.

For the benefit of other members of the society the following is a reproduction of the spark test data distributed to the North West chapter members.

The following descriptions refer to the accompanying sketch which shows the characteristic sparks of different steels as thrown off by a grinding wheel. Briefed by Mr. Sweet.

Fig. A represents the spark as thrown from a special steel manufactured and to be used especially for magnets. It clearly demonstrates the advantage of this method of selecting steels by comparison; in other words, mark your favorite brands or grades and compare them with others. By practicing this method, there will be fewer taps and reamers made out of machinery steel, with

a corresponding decrease of forgings made out of metals that are too high in carbon. Touch the material lightly on wheel, observe individual sparks.

Fig. B is Mushet steel. This grade of air hardening or high-speed steel, is very easy to distinguish from other steels as the particles follow a broken line and are a very, very dark red, with an occasional manganese spark.

Manganese in tool steel above a certain per cent is a very injurious element. The characteristic of the manganese spark, Fig. C, is that it widely differs from the carbon spark in that it seems to shoot or explode at right of angles from its line of force. Each dart is subdivided into a number of white globules. With a little practice, the trained eye will soon detect the slightest trace of manganese in the iron or steels.

In the higher grades of carbon steels, the iron lines are practically eliminated, with an increase of the star-like explosions, Fig. D, which often divide and subdivide, causing a beautiful display of figures. This is probably due to the iron and carbon becoming so united that they are most easily attacked by the oxygen. Hence, the great danger of burning steel in the fire. It would be well to state that the higher the percentage of carbon, the more profuse the explosions and the shorter the distance from their source of heat.

Chromium and tungsten high-speed steels are very easily determined by the spark test. The particles seem to follow a broken line with a very slight explosion; just before they disappear the color is of chrome yellow; and shows no trace of a carbon spark, Fig. E.

In the lower grades of tool steel, which contain from 0.50 to 1.00 per cent carbon, the iron lines become less and less conspicuous, the forking of the luminous streak occurring very much more frequently, often subdividing; the lower, the less sparks, and further from the source of heat, Fig. F.

In mild steel, which contains a small percentage of carbon, the effect is at once noticeable by a division of forking of the luminous streak. This is owing to the progressive action of carbon which is acted upon by the maximum heat of the iron sparks, which then burning explosively, cause a break in the original heavy lines, Fig. G.

A piece of wrought iron, free from carbon, if held against the emery wheel, the end of the bar will be heated by friction. As the small particles are thrown from the wheel, they will follow a straight line, which becomes broader and more luminous some distance from the source of heat and then disappear as they started. Ths is probably due to the action of the air on the heated particles requiring some time to act. (Touch material lightly on wheel, observe individual sparks), Fig. H.

PHILADELPHIA CHAPTER

The Philadelphia chapter of the American Society for Steel Treating held a special meeting on Wednesday, April 11, 1923, at 8:15 p. m. in the Engineers club of Philadelphia, 1317 Spruce street, Philadelphia, Pa.

The speaker for this meeting was Dr. Zay Jeffries, metallurgist with the Aluminum Company of America, who presented a paper entitled "Hardness of Metals."

Dr. Jeffries is one of our foremost metallurgists in this country and has done a large amount of very valuable and interesting work on the theory and practice of metallurgy, both on ferrous and nonferrous materials.

Although Dr. Jeffries is one of our younger metallurgists, he has done a vast amount of research work and has correlated his own researches and that of many others into well defined and well founded theories, which are daily finding practical application in the industry.

The Philadelphia chapter enjoyed a very large turnout at this meeting and as evidenced by the large amount of interesting discussion following Dr. Jeffries' paper, it is quite evident that all who had the privilege of attending were well repaid.

PITTSBURGH CHAPTER

The Pittsburgh chapter of the American Society for Steel Treating held its regular April monthly meeting on Tuesday evening, April 3, 1923, at 8 p. m., in the Hawaiian room of the William Penn hotel.

The program for this meeting was a paper entitled "The Machinability of Tool Steels," presented by J. V. Emmons, metallurgist with the Cleveland Twist Drill Company of Cleveland, O.

Mr. Emmons has done a vast amount of work on the machinability of tool steels and incorporated in his paper data which he has been collecting for the past eight or ten years.

In his paper, Mr. Emmons brought out many valuable points of information to those who are especially interested in the machining of high carbon and alloy tool steels.

This meeting was exceedingly well attended and proved to be a decided success, as evidenced by the large amount of interesting and valuable discussion which followed the presentation of the paper of the evening.

RHODE ISLAND CHAPTER

The Rhode Island chapter of the American Society for Steel Treating held its regular April monthly meeting on Wednesday evening, the 25th, at 8:00 p. m., in the rooms of the Providence Engineering society, 44 Washington street, Providence, R. I.

The chapter was especially fortunate in having as speaker for this meeting A. H. Kingsbury, metallurgical engineer, at the Atha works, of the Crucible Steel Co. of America, Harrison, N. J., who presented a very interesting and capable paper entitled, "Tool Room Troubles."

Mr. Kingsbury has had charge of the high-speed and carbon steel production of the Crucible Steel Co. for many years. He has had many years practical experience in heat treating of steels as well as having had the opportunity of observing the difficulties of others in the heat treatment of tools.

The speaker handled his subject in an interesting and practical way,

bringing out many points of interest and help to the many members of the Rhode Island chapter who are vitally interested in the heat treatment of tools.

This meeting was well attended and proved to be a decided success.

The March meeting of the Rhode Island chapter was held Friday evening, March 16, 1923 in the rooms of the Providence Engineering society.

R. J. Allen, vice president of the National society was present and addressed the gathering, giving a resume of the work the society is doing.

The topic of the evening was, "What Happens When Steel Is Rolled and Why." Arthur Greene, chief of laboratory of the John Illingworth Steel company was the speaker. He illustrated his points with lantern slides, making the subject very clear and plain to all of the sixty or more members and friends present. After Mr. Greene's paper he was plied with questions on every phase of the manufacture of steel, answering them all very satisfactorily. Altogether, it was a very interesting and helpful meeting.

ROCKFORD CHAPTER

The Rockford chapter of the American Society for Steel Treating held its regular April meeting at the Nelson House on the evening of the thirteenth.

After the usual dinner Chairman Muehlemeyer opened the meeting and the nominations for next year's officers were presented by the nominating committee. Routine business was dispatched and Mr. Whipple, a member of the chapter and general manager of the Rockford Gas Company, a sustaining member, invited the chapter to visit the gas plant in a body, promising a complete sightseeing tour, entertainment and refreshments.

H. F. Wood, chairman of the Chicago chapter, was then introduced and talked on the "Uses and Possibilities of Heat Treatment." This was followed by quite a discussion. The paper was full of real dope (beneficial) and well worth while.

SCHENECTADY CHAPTER

The regular monthly meeting of the Schenectady chapter was held on Tuesday evening, April 3, at 8 o'clock in the Civil Engineering building, Union college.

The chapter was especially fortunate in having for the speaker at this meeting, Lawford H. Fry, metallurgist of the Standard Steel Works, Burham, Pa.

Mr. Fry, who is an authority on the subject of steel and its heat treatment, presented a very interesting and instructive paper entitled "Steel Treating," bringing out many valuable points of interest and instruction to the members present.

Following the presentation of this paper a large amount of interesting and valuable discussion ensued.

SOUTH BEND CHAPTER

The South Bend chapter of the American Society for Steel Treating held its regular monthly meeting April 11 in the number 2 plant of the Studebaker corporation.

The South Bend chapter was especially fortunate in having two speakers for this meeting, the first, J. A. White, of the Clark Equipment Co., Buchanan, Mich., presented a two-reel motion picture entitled "The Electric Furnace in the Steel Foundry." This picture was very interesting and brought out many points of information relative to the use of electric furnaces in the manufacture of steel castings.

The second speaker for this meeting was H. M. Boylston, professor of metallurgy at the Case School of Applied Science, Cleveland, O., who presented a paper entiled "Metallography and Its Application in the Inspection of Steel." Professor Boylston's paper dealt with the various types of photo-micrographic cameras available, also the technique involved in the preparation of specimens of steel for microscopic examination.

This meeting was especially well attended and proved to be a very decided success.

A lengthy discussion followed the presentation of these two papers.

SPRINGFIELD CHAPTER

The Springfield chapter of the American Society for Steel Treating held its regular monthly meeting on Friday evening, March 30, at 8 p. m., in the rooms of the chamber of commerce, 47 Worthington street, Springfield, Mass.

Professor Homerberg presented a paper entitled "The Microscope as an Aid in the Solution of Practical Steel Problems." Professor Homerberg is an expert metallographist and an authority on the subject. His paper was presented without the use of highly technical terms and was illustrated with stereopticon slides.

This meeting proved to be a decided success and developed a large amount of interesting and valuable discussion.

The Springfield chapter of the American Society for Steel Treating held its regular monthly meeting on Friday evening, April 27, at 8:00 p. m., in the Springfield Chamber of Commerce rooms, 47 Worthington street, Springfield, Mass.

Wm. R. Bennett, of Elmwood, Conn., was the speaker for this meeting and presented an interesting and capable paper entitled "Practical Steel Treating." This paper was a non-technical talk by a man who has long been connected with the heat treating business. His many years experience in the heat treating shop especially qualifies him to speak authoritatively on the practical shop viewpoints of heat treating.

Mr. Bennett reviewed the heat treatment of tools, carburizing and the general heat treament of materials.

The Springfield chapter enjoyed a very good turn-out and this meeting proved to be a decided success.

ST. LOUIS CHAPTER

The St. Louis chapter of the American Society for Steel Treating held a meeting on April 16, at which time M. M. Watkins presented a paper entitled, "The Application of Pyrometers, Past, Present and Future," which was illustrated with stereopticon slides. Mr. Watkins handled his paper in a very interesting way, bringing out many points of vital interest to the members concerned.

Well over 35 members and guests were present at this meeting, many of whom participated in the discussion which followed the speaker's paper.

TRI-CITY CHAPTER

The Tri-City chapter of the American Society for Steel Treating held its regular monthly meeting at the Davenport chamber of commerce, Thursday evening, April 26.

Harold F. Wood of the Ingalls-Shepherd division of the Wyman-Gordon Company, Harvey, Ill., presented a very capable paper entitled "The Management of Heat Treating Departments and the Determination of Heat Treating Costs."

Mr. Wood's paper was a very capable treatment of this subject. He has had a number of years of valuable experience in determining costs and handling heat-treating departments and has attacked the problem in a slightly different manner than is ordinarily used.

The item of depreciation has always been rather troublesome to handle and in his paper, Mr. Wood developed a definite procedure in the determination of depreciation based upon his observations and data obtained in past years.

The determination of heat-treating costs is a subject that merits considerable attention and it is sincerely hoped that more of our members will submit their views in paper form.

WASHINGTON CHAPTER

The Washington chapter of the American Society for Steel Treating held a joint meeting with the Washington Academy of Sciences, the Philosophical Society of Washington, and the Washington Society of Engineers on Saturday, March 31, in the auditorium of the Interior building, Eighteenth and F streets, N. W.

The speaker for this meeting was Dr. Walter Rosenhain, of the National Physical Laboratory of Teddington, England, who presented a paper entitled "The Structure and Constitution of Metallic Alloys." Dr. Rosenhain, who is a very eminent metallurgist, has done a vast amount of very valuable research in the study of metallic alloys and has advanced numerous theories as to their constitution.

Dr. Rosenhain has been in the United States for the past two months and has delivered numerous lectures before many of our American engineering and technical societies.

The paper which was presented before this joint meeting proved to be exceedingly interesting and dealt with research methods, apparatus and finally deductions and theories arrived at. Inasmuch as many of our members of the Washington chapter are doing work along this line, Dr. Rosenhain's

lecture proved to be very interesting.

This meeting was very well attended and was a decided success.

On April twentieth the Washington chapter held its regular monthly meeting in the auditorium of the new interior department building.

The first part of the program for the evening was a motion picture entitled "The Story of Alloy Steel" prepared by the Interstate Iron and Steel Co. The second part was the exhibition of a film entitled "The Story of the V-Type Eight Cylinder Motor Car" which was prepared by the Cadillac Motor Co. Both of these films were made and furnished through the courtesy of the United States bureau of mines.

This meeting was well attended and proved to be interesting to all.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A repesents Associate Member; S represents Sustaining Member; J represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

NEW MEMBERS

ADAMS, ROBT. B., (M-3), 2301 E. Vernon Avenue, Los Angeles, Cal.
AHRENS-FOX FIRE ENG. CO., (S-3), Cincinnati, Ohio.
ALLIS-CHALMERS MFG. CO., (S-2) Bullock Works, Cincinnati, Ohio.
AMERICAN HOIST & DERRICK CO., (S-4), 63 S. Robert St., St. Paul, Minn.
AMERICAN PULLEY CO., (S-4), 4200 Wissahicken Avenue, Philadelphia, Pa.
AMERICAN ROLLING MILL CO., (S-3), Middletown, Ohio.
ANDREWS STEEL CO., (S-3), Newport, Ky.
BAKER, JOHN A., (M-3), 3855 Santa Fe Avenue, Los Angeles, Cal.
BARTON, H. J., (A-3), 776 Gladys Avenue, Los Angeles, Cal.
BLACKALL, F. S. JR., (M-4), Taft-Pierce Mfg. Co., Woonsocket, R. I.
BOEHM, GEO. P., (M-4), 2116 W. Oakley Avenue, Chicago, Ill.
BROOKS, J., (M-3), Sargent & Co., New Haven, Conn.
CARMODY, A. J., (M-4), 221 Market St., Hartford, Conn.
CAREY J. E., (M-1), 268 Bryant Avenue, Syracuse, N. Y.
CARY, C. R., (A-3), Leeds & Northrup Co., Philadelphia, Pa.
CATLUND, R. O., (M-3), Madsen Iron Works, Huntington Park, Cal.
CINCINNATI MILLING MACHINE CO., (S-3), Cincinnati, O.
COLLIER, J. R., (M-3), 1332 Lakeland Avenue, Lakewood, O.
CONNELL, W. L., (M-10), 2932 First Ave., S., Minneapolis, Minn.
DRENK, C. F., (M-3), 233 Marconi St., Huntington Park, Cal.
DUCHEMIN, F. J., (M-3), 4734 Main Ave., St. Bernard, Ohio.
EARL, S. R., (M-3), 2227 E. 38th St., Los Angeles, Cal.
ERICSON, C. A., (M-4), 523 S. 4th Street, Minneapolis, Minn.
FARRAR, WM. W., (A-3), 769 Central Ave., Los Angeles, Cal.
FOSTER, C. S., (M-5), Fales-Jenks Machine Co., Pawtucket, R. I.
FURMAN, W. F., (A-3), Cutler Steel Company, New York City.
GARDNER H. L. V., (M-4), 124 Clover St., Syracuse, N. Y.
GIBBONS, F. L., (A-4), Central Steel Co., 904 Swetland Bldg., Cleveland, O.
GRAHAM, C. A., (M-4), 14656 Scripps Ave., Detroit, Mich.
HAGLUND, A. G., (M-3), 1124 Spence St., Los Angeles, Cal.
HARRY, H. E., (M-4), 89 Stevens Ave., Highland Park, Mich.
HOLMES, R. M., (M-4), 513 E. Dayton St., South Bend, Ind.
HUPP MOTOR CAR CORP., (S-4), Detroit, Mich.
JARDH, W., (M-3), 348 W. 68th St., Los Angeles Cal.
JOHNSON, V. G., (M-3), 520 Leland Ave., Waterloo, Iowa.
JONES, R. H., (A-3), 1400 Portland Ave., Minneapolis, Minn.
KING, W. A., (M-4), Abbott Ball Co., Elmwood, Conn.
KNOX, N. R., (M-3), 285 Ogden Ave., Milwaukee, Wis.
LAMBERT, P. F., (M-3), Box 171, Stockdale, Pa.
LAWRENCE, T. J., (M-4), 4305 Virginia Park, Detroit, Mich.
LONGLEY, G. S., (A-3), 162 Capitol Ave., Hartford, Conn.
MEAD, L. W., (A-3), 1537 West Ave., Los Angeles, Cal.
MILLER, C. P., (M-3), 1726 S. Oxford Ave., Los Angeles, Cal.
MOLINE PLOW CO., (S-4), Plow Works, Moline, Ill., Att: E. R. Guyer.
MOLINE PLOW CO., (S-3), Tractor Works, Moline, Ill., Att: C. B. Rose.

MORELAND, G. E., (M-3) Box 937—R. F. D. No. 2 Los Angeles, Cal.
MORSE, A. J., (M-3), 2176 E. 9th St., Los Angeles, Cal.
NENNINGER, L. E., (M-3), 2745 Erie Ave., Cincinnati, O.
NICHOLLS, V., (M-4), 940 W. Linden St., Bethlehem, Pa.
NILES TOOL WORKS CO., (S-3), Hamilton, O.
OBERHELLMAN, T. A., (M-3), 2801 LaSalle St., St. Louis, Mo.
OPPENHEIMER, A. E., (M-3), 2019-7th Ave., Moline, Ill.
OUTCALT, D. D. A., (Sb-3), 2124 N Anderson St., Tacoma, Wash.
PAYNE, H. F., (M-4), c/o 3701 Cortland St., Chicago, Ill.
PITCHER, B. G., (A-2), Keystone Refractories Co., 120 Liberty St., New York City.
POLLAK STEEL CO., (S-3), Cincinnati, O.
POTTER C. B., (A-4), 1900 Wrigley Bldg., Chicago, Ill.
R. & V. MOTOR CO., (S-4), Att: H. A. Holder, Pres., E. Moline, Ill.
RICH STEEL PRODUCTS CO., (S-3), 3855 Santa Fe Ave., Los Angeles, Cal.
ROCKFORD GAS LIGHT & COKE CO., (S-4), 201 Mulberry St., Rockford, Ill.
ROHLAND, L. E., (A-3), Poldi Steel Corp. of America, New York City.
SCULLEN, D. V., (M-4), 60 Euclid Ave. W., Detroit, Mich.
SHAFER, G. E., (M-4), Rickert-Shafer Co., Erie, Pa.
SHERMAN, J. D., (M-4), 187 Dufferin St., Toronto, Ont., Can.
STANEK, E., (M-3), 4247 W. Cullerton St., Chicago, Ill.
STEELE, WM. A., (Jr-3), 5511 Baywood St., Pittsburgh, Pa.
STEPHAN, G. B. Jr., (M-3), 13 Barnett St., New Haven, Conn.
STOKES, J. E., (M-4), 420 Grandview Blvd., Bethlehem, Pa.
THRASHER, C. O., (M-3), 2227 E. 38th St., Los Angeles, Cal.
TOOL STEEL GEAR & PINION CO., (S-2), Cincinnati, O.
TOWNLEY, C. F., (M-4), Gladstone Hotel, Detroit, Mich.
TRIMMER, C. R., (A-3), 412 Loan & Trust Bldg., Milwaukee, Wis.
U. S. PLAYING CARD CO., (S-4), Cincinnati, Ohio.
VOSMER, G. W., (M-4), 3319 Fairfield Ave., Cincinnati, O.
WELLS, A. J., (M-3), 3851 Santa Fe Ave., Los Angeles, Cal.
WESTPHAL, G. E., (M-3), 527 Haney Ave., South Bend, Ind.
WHITFORD, C., (M-3), 131 Baker Ave., Syracuse, N. Y.
WILD, C. J., (M-3), Box 639, Sta. "C", Los Angeles, Cal.
WITTEMAN, G. P., (A-3), 136 N. 50th St., Philadelphia, Pa.
WOLFE, H. L., (M-4), Rockford Gas Light & Coke Co., Rockford, Ill.
WRAY, T., (M-4), Washburn Wire Co., Providence, R. I.
YELLOW SLEEVE VALVE ENG. WORKS, INC., (S-3), c/o A. A. Gustafson, E. Moline, Ill.

CHANGES OF ADDRESS

BAKER, R. E., from Rock Island Arsenal, Rock Island, Ill., to Box 286, Cleveland, Tenn.
BECKER, M. E., from 329 Church St. to 368 Main St. Hartford, Conn.
BELIAEFF, S. S., from P. O. Box 44, Troy, N. Y., to P. O. Box 189, Passaic, N. Y.
BIXBY, A. B., from 315 Peebles St., Sewickley, to 41 Harwood St., Pittsburgh, Pa.
CLARK, K. L., from 572 W. Randolph St., to 400 N. Sangamon St., Chicago, Ill.
COMSTOCK, G. D., from 208 Farmington Ave., Hartford, to 675 Broad St, Meriden, Conn.
CROSSMAN, L., from 27 Richards St., Worcester, Mass., to 285 Main St., Bristol, Conn.
DAVIS, G. F., from Bowling Green, Mo. to 715 S. Walnut Bucyrus, O.
ECKENRODE, C. A., from 3441 Forbes St., to 351 Darrah St., Pittsburgh, Pa.
EMERY, R. E., from Crucible Steel Co. of America, LaBelle Works, to 525 Union Trust Bldg., Pittsburgh, Pa.
FREDERICK, J. B., from 2203 Auburn St., to Care Pool Hotel, Rockford, Ill.
HALBING, J. E., from Ingersoll Rand Co., to 631 Barrymore St., Phillipsburg, N. J.
HART, A., from 107 Liberty St., to 44 Whitehall St., New York City.

HOVEN, J. R., from 823 Washington Ave., to 424 Tribune Annex, Minneapolis, Minn.
HULL, J. E., from 20 Mathewson St., to P.O. Box 1, Providence, R. I.
KRYNITSKY, A. I., from P.O. Box 258 to 3609 37th St., Mt. Ranier, Md.
LASCHUK, S., from 835 N. Robey St., to 733 S. Karlov Ave., Chicago, Ill.
LEONARD, S. C., from 5307 Cornell Ave., to 5525 Hyde Park Blvd., Chicago, Ill.
LUCAS, H., from Apt. A, 414 W. Washington to 312 S. Wm. St., South Bend, Ind.
McLEAN, John, from 51 Galt St., to 8 Fulton Ave., Sherbrook, Quebec, Can.
MAROT, E. H., from 2301 W. Euclid Ave., to 7404 Hanover St., Detroit, Mich.
McBRIDE, A. T., from 311 Beech St., to Edgewater Steel Co., Oakmont, Pa.
MILLER, C. C., from 2611 Madison St., to 2622 Jefferson St., N.E., Minneapolis, Minn.
MIRANDO, J. F., from 1030 Cypress St., to 3123 Ogden Ave., Chicago, Ill.
NESSER, J. O., from 7705 John R., to 10230 Oakland Ave., Detroit, Mich.
OSWALD, G. J., from 116 Colorado Ave., to 2322 N. Main St, Dayton, O.
PITTS, C. M., from Althea Ave., to 1110 Guilford Ave., Baltimore, Md.
QUINN, J. M., from 34 Lavin Court, Troy, N. Y., to 5309 Prairie Ave., Chicago, Ill.
REICHHELM, P. F., from 24 John St., New York City to Elizabeth, N. J.
RINEK, J., from Crucible Steel Co. of America, Jersey City, N. J., to Crucible Steel Co. of America, Harrison, N. J.
STARGARDTER, A. R., from Marlborough Apts., Baltimore, Md., to 2416 "B" St., Granite City, Ill.
TAPPER, G. W., from 413 Seitz Bldg., to 508 Turtle St., Syracuse, N. Y.
TUCKER, W. L., from 606 N. Pine Ave., Chicago, Ill., to 42 Commercial Rd., Hyde Park, South Australia.
VAN DYKE, F. J., from 3470 Gibson to 2181 Cortland Ave., Detroit, Mich.
WOODWARD, A. F., from 69 Stevens St., to 49 Second St., Lowell, Mass.

MAIL RETURNED

FOWLER, H. R., 42 Orchard Street, Cambridge, Mass.
SATTER, F. N., 968 Eddy Road, Cleveland, Ohio.
SCHINDLER, Arthur, 6146 15th Street, Detroit, Mich.

Items of Interest

THE Ludlum Steel Co. announce that they have recently opened a Boston office which is in charge of E. R. S. Reeder. Prior to the opening of this office the Wheelock, Lovejoy & Co. of Cambridge, Mass., were the local representatives of the Ludlum Steel Co. Mr. Reeder has been branch manager for many years and recent manager of the tool steel sales of the Wheelock, Lovejoy & Co.

The new office is located at 1004 Little building, 80 Boylston street, Boston, Mass. The general office of the Ludlum Steel Co. is at Watervliet, New York.

Charles T. Bragg, formerly chief metallurgist of the Michigan Smelting & Refining Co. and more recently president of the Michigan Valve & Foundry Co., has resigned from the latter position.

Henry J. Fischbeck is in charge of heat-treating for the Lawrence Aero-Engine Corp., New York City. He was previously foreman for the Wright Aeronautical Corp., Paterson, N. J.

The Witherow Steel Co. of Pittsburgh, has plans in progress for extensions and improvements at its plant at Neville island, to double, approximately, the present capacity. The company has recently formed a merger with the River Front Land Co. in this section, and has advanced its capital to $2,800,000 for general expansion. W. P. Witherow is president and Joseph Dilworth secretary of the company.

The Youngstown Sheet & Tube Co. has removed its Pittsburgh office from 1626 Oliver building to the suite formerly occupied by the Brier Hill Steel Co., rooms 1912-1914.

The Bureau of Standards has studied the ingot structure of ingots of invar (Fe:Ni 65:35) and the relation of the structure to the forgeability of the alloy. It has been found that ingots cast in chilled molds cool too slowly and form excessively large columnar crystals, producing a very brittle ingot which breaks readily on forging. To correct this difficulty a specially designed and refrigerated mold must probably be used.

The Pittsburgh station of the United States Bureau of Mines is devising

an instrument to record continuously carbon monoxide over a range of concentrations up to about 10 parts in 10,000. When the instrument is set up, it will be calibrated with known mixtures of carbon monoxide in air. If it proves practicable, the instrument can be used around blast furnaces, metallurgical and chemical plants and other places where a carbon monoxide hazard exists.

"Metals and Their Alloys," a very capable volume written by Charles Vickers, has recently been published by H. C. Baird & Co., 2 West Forty-fifth street, New York city.

This capable volume, while being partly based on "Metallic Alloys," by W. T. Brannt, has had so many revisions and additions by Mr. Vickers that a new book has resulted.

Many years of intimate contact and experience in the casting industry has fitted the author admirably for this work. The book is admirably fitted to the needs of the plant manager, the metallurgist, the chemist, or the worker in the shop. It is intensely practical and has been given a simple and direct treatment.

The author discusses the casting of copper, the making of manganese bronze, aluminum bronze, aluminum alloys, red brass, yellow brass, machine metals, and nickel alloys, together with their physical properties and attending peculiarities. The physical properties including strength, ductility, toughness, lightness, color, hardness, conductivity and resistivity, or the properties which make them admirably suited for bearings are dealt with in this volume. Many valuable formulas are included in this work. These formulas are given in such a way as to be easily understood by even the novice and the methods and procedure of mixing metals are set forth in considerable detail.

Some of the new and less frequently met with alloys are discussed. In addition there is a chapter that deals with die-casting, die-casting methods, die-casting bronze, and some of the lower melting point die-casting metals.

For those interested in the origin and physical properties of the elements; the methods of obtaining them from their ores and refining them, will find the large amount of information included in this book to be of considerable value.

In addition to the work taken from Brannt, entirely new chapters have been added to modernize the work thus bringing it up with the great developments of the industry within recent years.

"Metals and Their Alloys" is a thoroughly practical book, descriptive of the best American practices in dealing with metals and their alloys and is undoubtedly unapproached by any similar work in any language. There is no doubt that it will fill a long felt want in the industry and one which it aims to cover.

The volume is 6 x 9, containing 760 pages, and is bound in cloth. Price, $7.50.

The Bethlehem Steel Co. has announced the following appointments of individuals who were in the sales organiation of the Midvale Steel & Ordnance Co.: L. B. Morris, Midvale New York district sales manager, is now Bethlehem representative located in the Monadnock building, San Francisco. J. L. Adams has been appointed sales agent of Bethlehem in Cincinnati, and J. E. McLain, former Midvale Pittsburgh sales manager becomes Bethlehem Pittsburgh sales agent. A. C. Howell, Midvale Philadelphia district sales manager becomes plate sales agent for Bethlehem. L. R. Steuer has been put in charge of general sales of billets, wire rods, etc., with headquarters at Bethlehem, Pa.

The Chicago Flexible Shaft Co., 5600 Roosevelt road, Chicago, have available for distribution a new folder on their Stewart industrial furnaces. These are built for a wide number of uses, including annealing, carburizing, hardening, drop forging, high-speed steel, tempering, metal melting, and welding. Particular stress is laid on the proper equipment for high speed steel; advantages named for the company's furnaces are: minimum of heat radiation with consequent uniform temperature, accurate control, and decreased fuel consumption.

The publishers, Adam Hilger, Ltd., 75 A Camden Road, London, Eng., announce that the book entitled, "Wavelength Tables for Spectrum Analysis," compiled by F. Twyman, F. Inst. P., is now ready for distribution.

This book is a collection of wavelength tables intended for use in the laboratory, containing only matter essential for this purpose. It comprises standard wavelengths from 2375 to 8495, I.A., the persistent and sensitive lines of most of the elements arranged under the name of each element and the most persistent lines arranged in the order of wavelengths.

There is also a list of wavelengths useful in the determination of stellar radial velocities.

For the standard wavelengths the recommendations of the International Solar Union and the International Astronomical Union have been followed.

For the tables of distinctive lines of the elements, the results of Hartley, of Leonard & Pollok and of A. de Gramont have alone been utilized. The object has been not to give complete tables of the wavelengths of the elements but to give those lines which are present when the quantity of the element is extremely small, and the authors cited are the ones who have given this problem most attention.

R. H. Goodrich has become engineer for the Detroit Motor Casting Co., Detroit.

TRANSACTIONS

of the

American Society for Steel Treating

Vol. III Cleveland, June, 1923 No. 9

PROGRESS IN FATIGUE OF METALS INVESTIGATION

DURING the year 1922, definite and important progress was made in the experimental work of the Fatigue of Metals Investigation at the Engineering Experiment Station of the University of Illinois. Engineering Foundation has continued its co-operation and the committee of the National Research Council has advised on program and report. A second report giving results and conclusions in detail, the Bulletin No. 136, of the Experiment Station has recently been distributed.

Interest in this investigation has spread and its practical value has come to be more widely appreciated. During 1922 outside funds for support of the project came wholly from the General Electric Co. Its officers have expressed high satisfaction with the work done.

Extension for two years is assured by the provision of additional funds to the amount of $30,000. The University of Illinois, the National Research Council and Engineering Foundation will continue to co-operate. The following industries will participate financially and in other ways: General Electric Company by a substantial addition to its preceding investment of $30,000; the Allis-Chalmers Manufacturing Company, the Copper and Brass Research Association, representing the most important producers and manufacturers of copper and its alloys, and the Western Electric Company. Several other companies are expected to join, in addition to a number mentioned in the first report (Bulletin No. 124, of the Engineering Experiment Station), which contributed materials and services of considerable value.

On the new part of the program are tests of steels at high temperatures, such as obtain in modern steam-engineering equipment and in internal-combustion engines, and a study of nonferrous metals, particularly the copper alloys.

The investigation continues under the immediate charge of Prof. H. F. Moore and has the general supervision of Prof. Arthur N. Talbot, as the head of the Department of Theoretical and Applied Mechanics, in the Engineering College of the University of Illinois.

CONFERENCE PERTAINING TO THE MANUFACTURE AND USE OF SCIENTIFIC INSTRUMENTS RECENTLY HELD

A CONFERENCE of men interested in the use or the manufacture of scientific instruments and apparatus was held recently at the headquarters of the National Research Council in Washington, D. C.,

at the call of the Council. It was attended by members of government scientific bureaus, scientific societies, universities, the Association of Scientific Apparatus Manufactures and individual firms. Dr. Burgess, director of the Bureau of Standards, presided.

A committee appointed by the chairman brought in a report which was adopted. This proposed that a committee of apparatus makers and users should be formed under the Research Extension division of the Council. This Committee is to consist of one representative from each of the following technical societies and organizations:

American Chemical Society, American Physical Society, American Institute of Electrical Engineers, Optical Society of America, American Electrochemical Society, American Ceramics Society, the Association of Educational Buyers, the American Society for Testing Materials, the Engineering Chemists Association, the American Society for Steel Treating, the Society of Automotive Engineers, and two representatives from the Bureau of Standards and the National Research Council and six representatives from the Association of Scientific Apparatus Manufacturers of the U. S. A. with members at large to be appointed by this committee.

The following were appointed to serve as members-at-large until their successors are chosen:

Hermann Kellner of Bausch & Lomb Optical Company, A. L. Day of the Corning Glass Works, H. B. Williams of the Society of Automotive Engineers, H. E. Ives of the Westetrn Electric Company and C. E. K. Mees of the Eastman Kodak Company.

The following were selected to act as an executive committee until their successors are chosen by the main committee:

W. M. Corse of the National Research Council, chairman; Paul Moore of the National Research Council, secretary; W. D. Collins, Geological Survey, F. K. Richtmyer, Cornell University; M. E. Leeds, president of the Association of Scientific Apparatus Manufacturers; John Roberts, secretary of the Association of Scientific Apparatus Manufacturers and G. K. Burgess, director of the Bureau of Standards.

It was agreed that there should be held at least one meeting a year of the general committee, and it is hoped that this can be arranged to take place on the third Thursday in April. This meeting is to be open to all interested. It was decided that the executive committee named should consider the proceedings of the conference and initiate any projects which might seem advisable.

Dr. Vernon Kellogg in welcoming the conference, spoke of the importance of little things, and indicated the progress science had made with the development of the instruments for learning the truth.

The discussion—for the whole purpose of the conference was to bring face to face in a frank conference men interested in the use, the manufacture and the sale of apparatus, centered around (1) Apparatus supply, under the heads importation, domestic apparatus manufacture, instrument shop of research and college laboratories, manufacture of special apparatus not now made in the United States; (2) Standardization of apparatus, under the heads of limitation of types and sizes, standardization of parts, standardization of methods; (3) information service, under the heads—sources of information, finding list, scientific bulletin concerning apparatus and use and (4) Inspection service.

GEORGE KIMBALL BURGESS
Nominee for National President of the Society

REPORT OF NOMINATING COMMITTEE

To the Secretary of the American Society for Steel Treating

The National Nominating committee, meeting according to the constitution of the American Society for Steel Treating, selected as unanimous choice of those present the following men for nominees for office:

President—George Kimball Burgess, Washington, D. C.
Second Vice President—Robert M. Bird, Bethlehem, Pa.
Treasurer—Zay Jeffries, Cleveland.
Director—J. Fletcher Harper, Milwaukee.

According to Section 10 of Articles VII of the by-laws, we are enclosing the written consent of these gentlemen to their nomination.

Yours very truly,

NATIONAL NOMINATING COMMITTEE
American Society for Steel Treating

(Signed) JEROME STRAUSS
C. B. SWANDER
C. E. McQUIGG
H. J. STAGG, Chairman.

Biography of Nominees for Offices in the National Society

George Kimball Burgess

Nominated for National President of the Society

BORN at Newton, Mass., Jan. 4, 1874, having descended from Puritan ancestry, he received his early education in his native city receiving his first degree from the Massachusetts Institute of Technology, where he was instructor in physics for two years after his graduation. Going to Paris he completed his graduate work and received the degree of Doctor of Science at the University of Paris. Upon his return to the United States he became instructor at the University of Michigan for one year, and at the University of California for two years, after which he went to Washington, D. C., and entered the Bureau of Standards as associate physicist and was placed in charge of pyrometry. Out of this grew the division of metallurgy which was established in 1913 with Dr. Burgess in charge as chief physicist, in which capacity he continued until April 23, 1923, when President Harding appointed him as Director of the Bureau of Standards succeeding Dr. Stratton.

Dr. Burgess' acquaintance with the French language has borne fruit in the translation of Duheim's "Thermodynamics and Chemistry," and the publication of "Reserches sur la Constante de Gravitation." Perhaps his best known book is the translation of LeChatelier's work on the "Measurement of High Temperature," which later being enlarged and modernized by him, became the standard English work on pyrometry. While temperature measurement is not one of the phases of the metallurgical division of the Bureau of Standards, nevertheless Dr. Burgess has always shown a keen interest in pyrometry and has never missed a timely opportunity to emphasize the necessity for accurate thermal control in modern metallurgical operations. He has made many technical and scientifical contributions to the numerous scientific societies. Dr. Burgess is a member of the American Society for Testing Materials of which he is now president; the National Academy of Sciences; the American Institute of Mining and Metallurgical Engineers; Iron and

Steel Institute of Great Britain; the Washington Academy of Sciences and the Philosophical Society of Washington, of which he is past-president, the French Physical Society and the American Society for Steel Treating.

Of his many other activities he is chairman of the Board of Federal Specifications of the Bureau of the Budget which has charge of preparing specifications for materials purchased by the government, and he is a member of the National Research council. He represents the Department of Commerce in dealing with the preparation of standards of engineering materials and practices in connection with the work of the American Engineering Society Committee.

ROBERT M. BIRD
Nominee for 2nd Vice President of the Society

ZAY JEFFRIES
Nominee for National Treasurer of the Society

Robert M. Bird

Nominated Second Vice President of the Society

BORN at Bethlehem, Pa., Sept. 17, 1882, he was graduated from Lehigh University in 1902 with the degree of M. E.

Since his graduation he has been with the Bethlehem Steel Co. as superintendent of treatment departments, superintendent of Lehigh merchant mills, metallurgist and now as engineer of tests at the Bethlehem plants.

Mr. Bird has been very active in the art and sciences of metallurgy, having memberships in the American Institute of Mining and Metallurgical Engineers; American Society for Testing Materials; Society of Automotive Engineers—Steel Standards Division; American Iron and Steel Institute; British Iron and Steel Institute and the American Society for Steel Treating.

Zay Jeffries

Nominated Treasurer of the Society

BORN at Willow Lake, South Dakota, April 22, 1888, he was graduated from the South Dakota State School of Mines, Rapid City, S. D., in 1910 with the degree of Bachelor of Science in Mining Engineering. In 1914 he received the degree of Mining Engineer at the same school. Between the years 1911 and 1916 he was instructor in metallurgy at Case School of Applied Science, Cleveland, and in 1916 and 1917 was appointed Assistant Professor of Metallurgy at the same school.

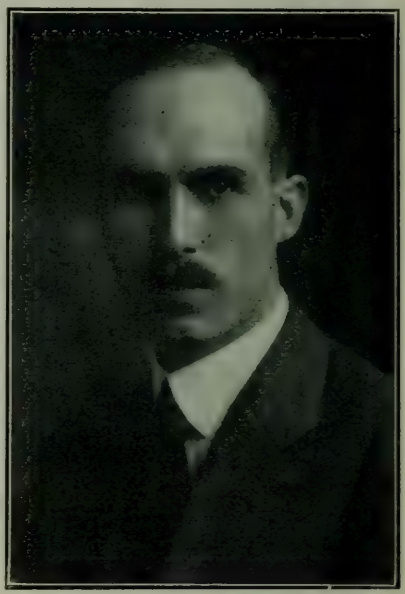
At the present time Dr. Jeffries is in charge of the Cleveland Section of the Research Bureau of the Aluminum Company of America and is consulting metallurgist for the National Lamp Works of the General Electric Co.

J. Fletcher Harper

Nominated Director of the Society

ATTENDED the University of Wisconsin for three and one half years, taking electrical engineering, following which he served a special apprentice course at the Allis Chalmers Mfg. Co. Was connected with the Northwestern Mfg. Co., Milwaukee for one year, returning to the Allis Chalmers Mfg. Co. in July 1916 to take charge of the heat treating departments. In Sept. 1918 he was made assistant superintendent of the forge department in the same plant. In April 1921 he was made research engineer of the manufacturing department of the Allis Chalmers Mfg. Co., which position he still holds.

Mr. Harper served as a member of the board of directors of the American Steel Treaters Society, 1919-20.



J. FLETCHER HARPER
Nominee for Director of the Society

VOLUME III TRANSACTIONS COMPLETED

THE June issue of TRANSACTIONS completes Volume III. Included in the June issue is the author and subject index for Volume III.

All of those who desire to have their separate copies bound in accordance with the style which has been used in binding Volumes I and II, may forward their copies to the Executive Offices of the Society, 4600 Prospect Ave., Cleveland, together with $2.00 and they will be bound and returned to the owner promptly.

We urge that all of our members avail themselves of this opportunity of having this work done at this low cost as we are sure that TRANSACTIONS in the bound form will be of greater service and will make an invaluable addition to your library.

THE MANUFACTURE AND INSPECTION OF LEAF SPRINGS

By H. G. Peebles

Abstract

This paper deals with the manufacture of leaf springs for use in the automotive industry. The author has reviewed one of the largest plants devoted to the production of springs and conducts his readers on a short journey through the plant pointing out those operations which are of prime interest.

The warehouse having a capacity for about 10,000 tons of steel is one of the salient points of interest, because it is here that the steel is unloaded from the cars, sorted, sampled, tested, and piled in its proper bin. Untiring vigilence in receiving steel in the warehouse, combined with an adequate system of records practically eliminates the factor of defective steel in production.

The author discusses the various microstructures and imperfections found in spring steels, illustrating them with photographs. Testing methods are likewise briefly reviewed.

Manufacturing methods, furnaces, electrical control of furnaces, mechanical quenching machines and the final capacity testing of springs is covered by the paper.

YOU are probably all familiar with the wonderful strides made in the quantity production of parts, in the automobile industry during the past decade. The manufacture of leaf springs, which constitute a very important part of an automobile, likewise has had to undergo revolutionary changes to keep pace with automobile production and their rigid requirements. In this paper, the author will give you an idea of how the chassis springs on your car are made today, in some of the most up-to-date plants, by taking you on a short inspection trip in one of the largest of these factories.

In beginning our trip, we will first visit the steel stock warehouse, which is conveniently located adjacent to the railroad siding where the cars may be unloaded with the minimum of handling of the incoming steel. Fig. 1 shows the stock bins arranged in the warehouse. The steel is handled by means of the overhead crane which is also shown in this picture.

Not many years ago these 25-foot bars were handled separately and by hand. While this method was alright for small production, it would be absolutely inadequate today, when as much as eight or ten carloads are often unloaded during one day. In addition to handling the incoming stock the crane, at the same time supplies five shears with material thus adding another two and a half carloads to its days work. In this picture you see the largest stock of leaf spring steel in the world, the capacity of these bins totaling about 10,000 tons, or 200 carloads. In these bins it is necessary to keep about 125 kinds and sizes of steel ranging from 1½ to 5 inches in width, and from 3/16 to ½ inch in thickness, of both carbon and alloy analyses, as well as several sizes of dead soft stock for making clips. This enormous stock is necessary

---

A paper presented before the Detroit Chapter of the Society. The author, H. G. Peebles is metallurgist with the Detroit Steel Products Co., Detroit, Michigan.

to tide over the periods when there is a steel shortage or railroad trouble. At such times you automobile men may be forcibly reminded of the lines:—

For want of a nail, the shoe was lost;
For want of a shoe, the horse was lost;
For want of the horse the rider was lost;
For want of the rider, the battle was lost;
And all for the want of a horseshoe nail.

Except that in this case it may be wheels, bodies, springs, or some other important part. Except for the labor part of it—the running of the crane and

Fig. 1—Warehouse Showing Steel Spring Stock Arranged in Numbered Bins. The Overhead Crane Serves the Purpose of Handling the Steel in Placing It in the Proper Bins as Well as Supplying the Shears With Steel for Production.

the handling of the chain around the bundles—all details of physical inspection, assignment, shear records and perpetual inventory are easily handled by one man.

Identity of Steel Accurately Maintained

Now a word here about the unique way in which the records of this stock are kept so as to take care of any possible trouble that might get past the routine inspection of the raw stock. You will notice that the bins are numbered. The contents of the bins are kept on record, not only in the form of a perpetual inventory as to the quantity of each size, but also in such form that the locations, amounts, and sizes of each heat and each car are known. Each heat of steel is given a laboratory serial number. If the same heat is received in three sizes in four cars, all these entries will appear on the one sheet in the laboratory. The daily record of steel sheared includes for each order the heat number, the bin number, the size and the kind of steel used on each plate. It should be stated here that the leaves or plates of a chassis spring are numbered consecutively from the long one down to the short one, the long leaf, which ordinarily has an eye at each end, being the main leaf, the back, or plate No. 1. Occasionally there is an extra plate placed on the inside of the camber or arch of the main leaf. This has no number, but is called an auxiliary plate. Under this arrangement, when trouble is encountered in production, for instance, a few soft plates in one job, indicating

a mixed heat of steel from the mill, the record of the steel sheared on that order will give the heat number, and the laboratory sheet will give the necessary data to enable locating all the remainder of that heat or that car, so that it can be resampled. Not only does this prevent further expensive trouble, but it enables the rejection of mixed stock even when the original sampling failed to detect the defective material. It also enables the stopping of all other orders in the process of manufacture, on which the same steel was used. Another unique point in this connection is that the stock clerk is held accountable only to the metallurgical department. This is the only arrangement by which this method of handling heats could be carried out successfully.

Inspection of Raw Stock

The inspection of raw stock starts when the notice of shipment is received in the laboratory. This contains the amount of each size and each heat, and the quoted analyses. This data is passed on to the stock clerk before the car is received, along with instructions as to sampling. The physical inspection of the incoming steel includes testing a large number of bars for width, thickness, and concavity, and examination for pipes, surface defects, and straightness. The width is tested with fixed maximum and minimum gages unless trouble is encountered. For gage and concavity it is necessary to use micrometers, as a few thousands of an inch may seriously affect the flexibility tests of the final inspection. In connection with the test for concavity it should be mentioned that the spring steel used in chassis springs is not flat, but is from five to thirty thousandths of an inch thinner at the center of the bar than it is at the edges, the concavity specified depending upon the width. This is necessary to enable perfect fitting of the leaves. Of course, too much concavity would weaken the spring leaves. The number of regular samples taken on the raw stock runs from one sample from each size of each heat in the car, where the customer has inspected the billets and analysis before rolling, up to as high as several samples from each bundle in case of trouble or a suspicion of trouble. In addition to these, numerous samples are taken for heat treatment tests. Each of these regular samples is subjected to complete chemical analysis, micro-analysis, and various physical tests.

The physical test pieces pass through the heat treating furnaces as coupons with production, and are then subjected to Brinell, bend and fracture tests, and occasionally to tensile and vibratory tests. These coupons are filed so that they are available for microsections, as a check upon heat treatment, although this is not necessary, once the time and temperature for a kind and size of steel have been established.

Microscopic Examinations

In the microscopic analysis, the sample is normalized in a furnace having a reducing atmosphere and cooled slowly enough to develop the pearlite and either ferrite or cementite, as the case may be. The section which is polished and examined under the microscope covers a little over half of the cross section of the bar, or all of the center of the bar and one edge. This section is examined for pipes, slag or dirt, segregation, depth of scratches or seams, and decarburization, and the carbon content is estimated. The use of the microscope is deemed necessary for routine inspection, since, in a product which is made to withstand vibrations, segregated or dirty steel is as bad as incorrect analysis.

Before going into the details of the manufacturing of leaf springs we will

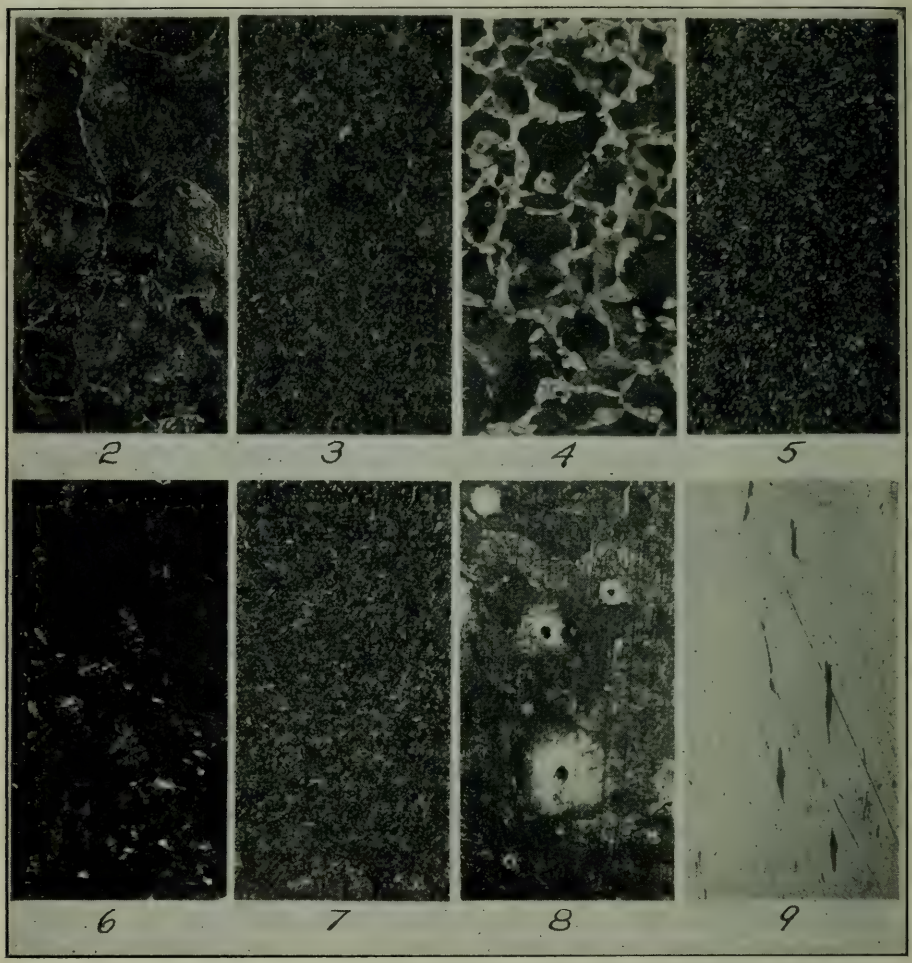


Fig. 2—Normalized Carbon Spring Steel Containing About 1 Per Cent Carbon and 0.4 Per Cent Manganese. Fig. 3—Same as Fig. 2 After a Proper Heat Treatment. Fig. 4—Normalized Silico-Manganese Spring Steel Having an Approximate Analysis of 0.5 Per Cent Carbon, 0.7 Per Cent Manganese and 2 Per Cent Silicon. Fig. 5—Same as Fig. 4 After a Proper Heat Treatment. Fig. 6—Normalized Chrome-Vanadium Spring Steel Having an Approximate Analysis of 0.5 Per Cent Carbon, 0.8 Per Cent Manganese, 1 Per Cent Chromium and 0.17 Per Cent Vanadium. Fig. 7—Same as Fig. 6 After a Proper Heat Treatment. Fig. 8—Dirty Steel. Fig. 9—Dirty Steel Showing Layers of Slag. This Specimen is a Cross-section and Not a Longitudinal Section. All Photomicrographs Have a Magnification of $\times 100$.

first look at a few of the various structures of steels as seen through the microscope. These are shown in Figs. 2 to 14. Fig. 2 shows a normalized carbon spring steel containing about 1.0 per cent carbon and 0.4 per cent manganese, and Fig. 3 shows it after a proper heat treatment.

Fig. 4 shows a silico-manganese spring steel in the normalized condition. The analysis specified for this steel varies considerably, but will average about 0.5 per cent carbon, 0.7 per cent manganese, and about 2.0 per cent silicon, and is shown in Fig. 5 after a proper heat treatment.

In Fig. 6 is shown a chrome vanadium spring steel, normalized. Speci-

fications also vary somewhat for this type of steel, but will average about 0.5 per cent carbon, 0.8 per cent manganese, 1.0 per cent chromium, and 0.17 per cent vanadium. The microstructure of this steel after a proper heat treatment is shown in Fig. 7. Chrome molybdenum steel appears the same as chrome vanadium and has the same analysis, except that the vanadium is replaced with about 0.3 per cent molybdenum.

No photomicrographs of chrome-silico-manganese steel are shown, but the normalized structure is about an average of that of silico-manganese and chrome vanadium steels, as would be expected. An average analysis would be about 0.5 per cent carbon, 0.7 per cent manganese, 0.7 per cent chrome, and 0.5 per cent silicon.

Figs. 8, 9 and 10 show some of the defects that only the microscope can reveal. Figs. 8 and 9 show the microstructure of dirty steel. Fig. 9 shows layers of slag in a specimen of steel when the section was cut crosswise of the bar and *not* lengthwise. Neither was the photo taken at the center of the bar; but it represents most of the cross section of all eight samples taken in rejecting one heat of steel.

An example of excessive decarburization is shown in Fig. 10. Such a condition may reduce the effective strength of the plate to a noticeable degree if it penetrates too far. This may be encountered on the raw steel, or, more frequently, it comes from excessively high temperatures used in the old method of heat treating.

In Fig. 11 is shown a macrograph of a quenched test piece of carbon steel, several heats of which had to be rejected on account of hard and soft spots. The black spots are pure troostite and are soft, and the white areas are almost pure martensite and glass hard.

Fig. 12 shows a macrograph of carbon segregation. The white area in the left center of the upper sample showed about 1.15 per cent carbon, while the dark area at the right showed about 0.9 per cent. Fig. 13 shows what actually happened to the piece when it was quenched. Due to unequal expansion and contraction the core actually broke away from the shell.

A few other items that have to pass laboratory inspection, are bronze bushings, nickel steel center bolts, and clip steel. These are subjected to chemical analysis and examination under the miscroscope. Clip steel also has to pass the flat, cold bend test. Nickel steel bolts also have to be examined for heat treatment. If they are too hard the heads fly off; if too soft, they stretch.

Manufacture of Leaf Springs

With this brief review of the responsibility of the metallurgical department and incoming inspection department in inspecting, sorting and segregating the raw stock for the manufacture of leaf springs we will now pass on to the actual manufacture of the springs. After the steel has been sheared to the desired lengths, it is passed on to various other machines. The main leaves go to the eye machine, then to the machine which mills the eyes to width, and then to another which reams them to the correct internal diameter. On the eye machine are guides which insure the eye being at right angles to the plate. When the eyes leave the milling machine they are correct in width to within a few thousandths of an inch. Inspection here is important in preventing a loose fit and consequent side-play where the spring is fastened to the shackle or the chassis. The operations to which the other plates are

subjected are, punching, nibbing, diamond pointing, rolling and trimming. Plates used to be kept from slipping in the assembled spring by the use of nibs near the center of each plate, but this has been almost entirely replaced by the use of the centerbolt. Likewise it used to be customary to roll the ends of the plates to thinner cross-section to allow the even distribution of the load,

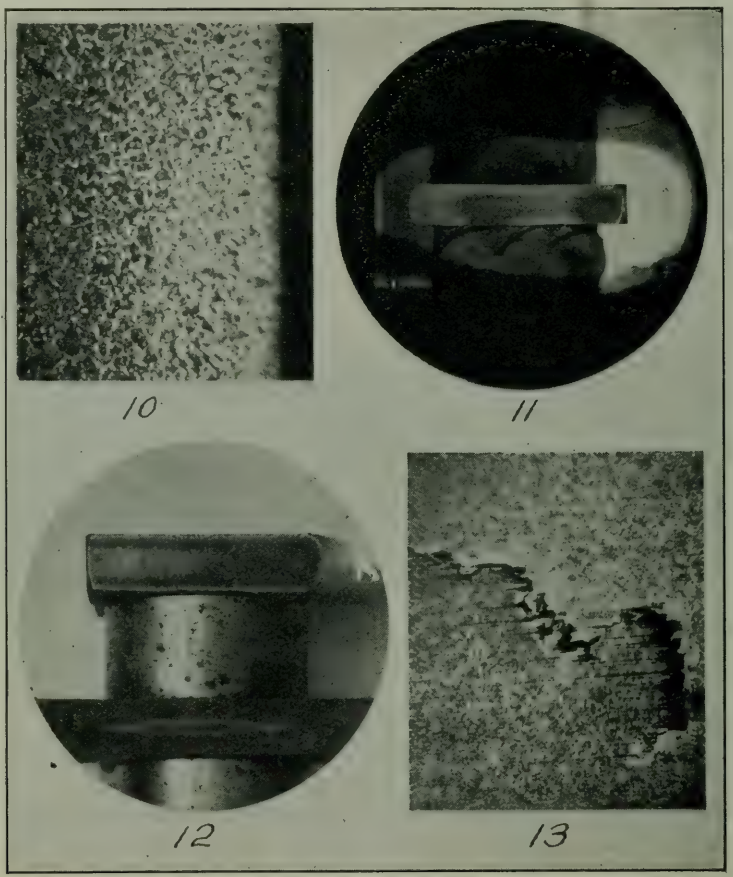


Fig. 10—Photomicrograph of Steel Showing Excessive Decarburization. The Dark Area at the Left is the Normal Structure. The Light Area at the Right is the Decarburized Layer. ×100. Fig. 11—Macrograph of a Quenched Test Piece of Spring Steel Which Had Been Rejected Due to Hard and Soft Spots. The Black Spots are Pure Troostite and are Soft, and the White Areas are Almost Pure Martensite and Glass Hard. Fig. 12—Macrograph Showing Carbon Segregation in Spring Steel. The White Area in the Left Center of the Upper Sample Showed About 1.15 Per Cent Carbon While the Dark Area at the Right Showed About 0.9 Per Cent Carbon. Fig. 13 Shows What Actually Happened to the Piece When It was Quenched. Due to Unequal Expansion and Contraction the Core Actually Broke Away From the Shell.

until someone discovered that almost exactly the same action could be obtained by simply trimming a little triangle of steel off from each corner of the plate. This process is called diamond pointing.

From these operations the next step is the forming and heat treating of the spring leaves. Fig. 14 shows the old method of forming, cambering or pinching the plates by hand. Carriage springs of the olden days used to be

formed this way from a high heat and when they had cooled to the proper shade of red they were thrust into water for a few seconds and then withdrawn so as to allow the remaining heat to draw the temper. Of course, they used lower carbon steel, but today we keep away from even traces of

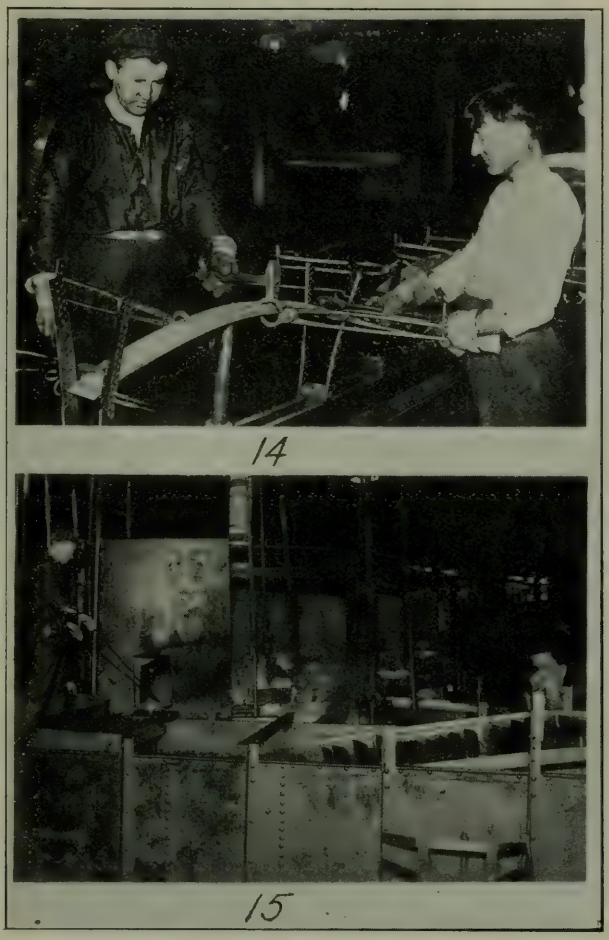


Fig. 14—Showing the Old Method of Forming, Cambering, or Pinching the Plates by Hand. Fig. 15—Showing a Rotating Hearth Furnace Which Has Given Good Service in Reheating Hand-Formed Plates. The Spring Leaves are Fed in on Edge at the Door at the Right and are Taken Out About One-Half Hour Later from the Door at the Left, After Traveling Almost a Complete Revolution of the Hearth Through Gradually Increasing Temperature Zones.

water. As soon as they started to make automobile springs this method was changed to the following procedure: Heat to *about* 1700 degrees Fahr. (emphasis on the *about*), pinch or form, quench in oil until nearly cold, then draw by the so-called flash method of putting the quenched plate back into the same furnace and leaving it until the oil had burned off! It may sound odd, but there were a few men in the country who could make pretty

fair springs this way. However, it would take about 1000 men with this good judgment for the day shift, and another 1000 for the night shift to keep this one factory going, not to mention the 500 furnaces that would be necessary! Later this routine was changed by eliminating the flash draw and substituting

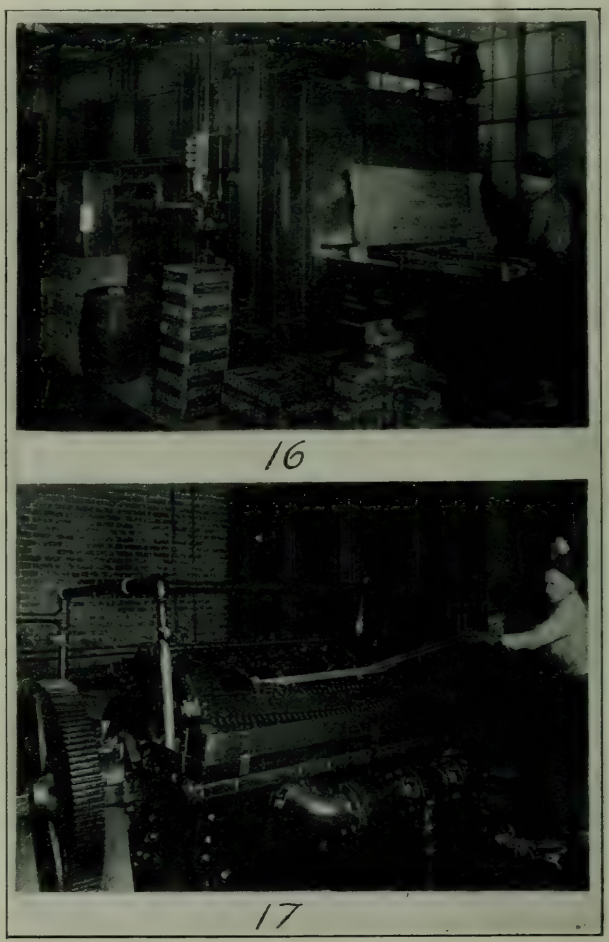


Fig. 16—One of the Latest Types of Continuous Furnaces for Heat Treating Steel Spring Leaves. There are Several Walking Beams Extending Lengthwise of the Furnace and are Operated by a Cam Through Slots in the Floor of the Furnace. The Spring Leaves are Lifted Clear of the Floor, the Beams Then Move Forward Several Inches and the Entire Contents of the Furnace are Deposited Again on the Floor of the Furnace a Few Inches Ahead of Their Previous Position. Fig. 17—Quenching Machine Which Receives the Heated Plates from the Furnace in Fig. 16 and Clamps Them Into the Proper Shape and Then Quenches Them in the Oil Bath.

a reheat in a furnace at a temperature of about 1000 degrees Fahr. This procedure is still followed in a few plants, but the high initial temperature necessary produces such a coarse grain in the steel, that it is not to be recommended. There is also a large percentage of soft plates, due to their cooling a little too far before entering the oil. Where hand forming is still

used, it is now customary to allow the plates to cool in the air after the cambering operation, then to reheat them to the correct temperature, quench in oil, and draw in either a low temperature furnace or in a salt bath. In the larger plants hand pinching is used only on jobs too small to warrant a machine set-up.

Heat Treatment

Before passing on to the heat treatment, the tempering oil system should be mentioned. All quenching tanks are connected with a circulating system of large capacity in which are large banks of cooling coils over which fine

Fig. 18—Showing Control Valves, Operating Panels and Pyrometric Recorder Which Constitute the Automatic Temperature Controlling Mechanism on Furnace Shown in Fig. 16. Fig. 19 Shows the Discharge End of an Endless Conveyor Type of Furnace Used to Draw the Temper of Quenched Spring Leaves.

streams of water flow, so that the temperature of the entire system, is kept constant within a few degrees. All tempering oil is tested before it is unloaded, to insure absolute uniformity. All tanks are tapped daily to remove traces of water that settle out.

In Fig. 15 is shown a furnace with a rotating hearth which has given good service in reheating hand-formed plates. The spring leaves are fed in on edge at the door at the right, and taken out about half an hour later from the door at the left, after traveling almost a complete revolution of the hearth through gradually increasing temperature zones. The temperature within this furnace is recorded from five thermocouples.

The feeding of the plates of raw steel into one of the latest types of continuous furnaces for heat treating work is shown in Fig. 16. The plates are handled in rotation, in the order in which they are finally assembled. There are three or four walking beams extending lengthwise of the furnace and operating by a cam action, through slots in the floor of the furnace. The spring leaves are lifted clear of the floor, the beams then move forward several inches, and the entire contents of the furnace are deposited again on the floor of the furnace a few inches ahead of their previous position. As the plates reach the other end of the furnace they are taken out through the tiny side door shown at the right in Fig. 17, and placed between the jaws of the machine. The operator then trips a lever, the jaws close, and the drum revolves until the redhot plate is submerged in the oil.

It remains clamped in the jaws under the oil until it is nearly the same temperature as the oil. About three or four seconds elapse between the time the plate leaves the hot furnace and the time it enters the oil.

Fig. 18 shows the control valves, operating panels, and recorders which constitute the automatic temperature controlling device used by the largest spring manufacturing plant on all of its cambering furnaces. The recorder is fitted with two sets of maximum and minimum contacts, which act inde-

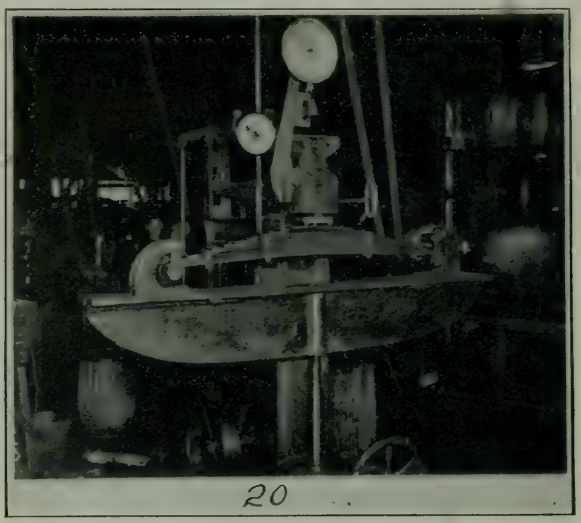


Fig. 20—Capacity Testing Machine for Determining the Load and Deflection of Finished and Assembled Leaf Springs.

pendently of each other. The action of one set of contacts is controlled by a thermocouple located in the preheating end of the furnace. This set, in turn, controls the relay and panel operating the valves for that end of the furnace. Likewise, the action of the other set of contacts on the recorder is controlled by a thermocouple in the soaking or finishing end of the furnace. This set operates the panel and valves for that end of the furnace. The recorder is an ordinary two-point continuous curve machine. The contacts on the recorder are adjustable so that any desired temperature can be maintained in either end of the furnace. The furnaces are gas-fired. The thermocouples extend 18 inches into the furnace, and as the tip of each is only a couple inches above the steel, the temperature of the steel affects them very quickly. The operation of the valves is such that there is always a small amount of gas flowing into the burner manifolds; but the desired temperatures are maintained by the length of the periods the valves stay open to maximum and the frequency with which they are opened. As it requires electric current to keep the valves open to maximum, in case of a breakdown in the power circuit the furnaces cool down to about 1200 degrees Fahr. instead of overheating. The maximum and minimum openings of the valves are also adjustable.

Fig. 19 shows the unloading end of an endless conveyor type of furnace used to draw the temper of the quenched plates. It takes about half an hour to pass through the heated zone which is at a temperature of about 900 degrees Fahr. There are still two or three large factories using salt baths instead of these furnaces for drawing.

As the plates come from the draw fires, they are tested for Brinell hardness. This should be between 350 and 418 on carbon steel, and 364 and 430 on alloy steel. As stated before, the heat treatment is also checked frequently through microsections of the coupons which accompany production through these furnaces.

While the plates are still hot from the draw fires, they are fitted, if necessary, so that each plate will bear evenly on the one next to it. The loose plates, still in the order they are found in the completed spring, now pass onto the conveyor where they are buffed, doped (greased), fitted with clips and bushings, and bolted together. They are then given the capacity test on a testing machine such as is shown in Fig. 20. When the upper dial indicates the specified load, the lower dial must indicate the required deflection. Another important test in the final inspection is for the parallelism of eyes.

In the days gone by we used a horse and carriage, but today we go at the speed of a railway train over roads that are not always as level as the rails over which the train passes. It is necessary, therefore, that the chassis springs of the modern automobile be made so that they will hold up for millions of vibrations under this rough treatment on the road.

While this paper has covered only in a brief way the manufacture of leaf springs it has endeavored to show the various steps required in the routine production of these components. The necessity for close inspection is paramount in obtaining rapid production through the shop, interchangeability in assembly and maximum life while in service.

EVIDENCES OF A CARBON-IRON EUTECTOID AND RESULTING MODIFICATION OF THE EQUILIBRIUM DIAGRAM

By Anson Hayes and W. J. Diederichs

Abstract

As indicated in the title of this paper the authors have correlated data which has been obtained recently partly by the present authors and partly by other investigators.

This paper points out that the abrupt change in the direction of the curve at 760 degrees Cent. (1400 degrees Fahr.) marks the completion of the absorption of heat due to the Ac_2 change. The second absorption which reaches a maximum at 800 degrees Cent. (1470 degrees Fahr.) is due to the simultaneous solution of Beta iron and carbon, and is therefore the carbon-iron eutectoid point on heating. The absence of an Ac_1 change is accounted for by the practical absence of combined carbon in completely malleablized iron.

THE writers have recently published a paper[1] presenting a theory for the mechanism of graphitization of white cast iron and high carbon steels. This theory, insofar as it referred to the completion of graphitization, was based upon the assumption that there existed a carbon-iron eutectoid. One of the purposes of this paper is to present considerable additional evidence which has more recently come to our attention.

In our previous paper, we reasoned from the evidence presented that there was a carbon-iron eutectoid located at the intersection of the carbon solubility line with the lines A_2 or $A_{2\text{-}3}$, and that this intersection was located at approximately 800 degrees Cent. (1472 degrees Fahr.)

The authors had planned a rather elaborate series of experiments to either prove or disprove the presence of this eutectoid. A considerable portion of this program was made unnecessary by the appearance of a paper by H. A. Schwartz[2] and co-workers. They present experimental data on white and malleable cast iron consisting of cooling curves, solubility of carbon under equilibrium conditions obtained both from white and malleable iron, and specific resistances of malleable iron reheated to various temperatures and quenched.

Fig. 1 is a reproduction of their cooling curve data. They state that this figure represents both heating and cooling curves on completely malleableized iron on initial and subsequent heating cycles.

The initial heating curve seems to show a heat evolution on heating. Such action, however, is contrary to the known action of equilibrium systems. Since the conditions that prevail in the process of manufacturing malleable iron must be admitted to be such as to approach those required to attain equilibrium conditions, a conclusion that such a heat evolution during this heating had occurred is untenable. Realizing the above difficulties, heating

1. TRANSACTIONS of American Society for Steel Treating, March, 1923.
2. *Transactions* of the Institute of Mining and Metallurgical Engineers, No. 1181S, August, 1922.

A paper written by Dr. Anson Hayes and W. J. Diederichs. Of the authors, Dr. Hayes is associate professor of physical chemistry and metallography and Mr. Diederichs is associate professor of mechanical engineering, Iowa State College, Ames, Iowa.

and cooling curves were repeated in this laboratory. The curves obtained duplicated those presented by Schwartz.

At this point we wish to call attention to a statement due to G. K. Burgess and J. J. Crowe[3] in discussing the forms of cooling curves. They state—"an examination of some of the heating curves will perhaps give the erroneous impression that Ac_2 is an evolution rather than an absorption of heat. The swingback at the maximum is very abrupt, following what appears to be a gradual building up of this maximum from an indeterminate low temperature." In view of these facts the initial heating

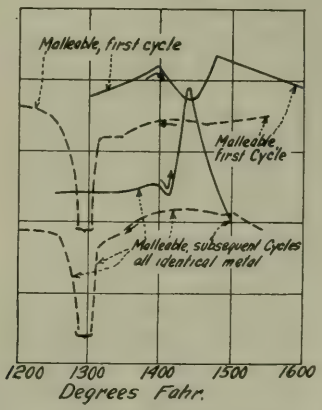


Fig. 1—Thermal Critical Points of Malleable Iron. (Schwartz.)

curve shown may be interpreted as follows: The abrupt change in the direction of the curve at 760 degrees Cent. (1400 degrees Fahr.) marks the completion of the absorption of heat due to the Ac_2 change. There is a marked swingback immediately after this change is completed. The second absorption which reaches a maximum at 800 degrees Cent. (1470 degrees Fahr.) is due to the simultaneous solution of Beta iron and carbon, and is therefore the carbon-iron eutectoid point on heating. The absence of an Ac_1 change is accounted for by the practical absence of combined carbon in completely malleablized iron.

The work of Howard Scott[4], "the Magnetic Change A_2 in Silicon and Chromium Steels," appeared at an opportune time to substantiate the above interpretation. He shows that Ac_2 is lowered at the rate of 21 degrees Cent., (70 degrees Fahr.) and that Ac_1 is raised 21 degrees Cent. (70 degrees Fahr.) for each per cent of silicon. He also shows that Ar_1 is raised at the rate of 18 degrees Cent., (64 degrees Fahr.) For an iron containing 1.2 per cent silicon the Ac_2 point (and therefore probably the Ar_2 point also, since the A_2 point occurs at the same temperature on heating and cooling) will occur at 758 degrees Cent. (1397 degrees Fahr.) This is in excellent agreement with the interpretations just given to the heating curve, since Schwartz reports this malleable iron as containing 1.26 per cent of silicon. Our interpretation placed the Ac_2

3. Critical Ranges A_2 and A_3 of Pure Iron; Bulletin of Bureau of Standards, Vol. 10, No. 3, page 365.
4. *Chemical and Metallurgical Engineering*, January 31, 1923.

point at 760 degrees Cent. (1400 degrees Fahr.) and in the light of Scott's work it should have appeared at 759 degrees Cent. (1397 degrees Fahr.).

Before attempting to interpret the initial cooling curve the following facts should be kept clearly in mind:

1. It can be assumed that the Ac_2 and Ar_2 points occur at identical temperatures since this is a characteristic of the A_2 transformation in steels.
2. In this particular cast iron, since silicon is 1.26 per cent, Ar_2 is at 759 degrees Cent. (1397 degrees Fahr.), according to the work of Scott.
3. The A_1 lags on either heating or cooling, and may therefore occur above A_2 on heating and below A_2 on cooling, depending upon the rate of temperature change.
4. Upon the initial heating of a completely malleablized iron preparatory to running a cooling curve, carbon goes into solid solution to approximately 0.6 per cent, the exact percentage depending somewhat upon the temperature to which the specimen is carried.

In discussing the initial cooling curve, it should be noted that there is no Ar_2 point evident at 760 degrees Cent. (1400 degrees Fahr.) as might be expected. It is to be remembered that as carbon concentration increases the Beta transformation merges with the A_1 transformation and is no longer evident. The occurence of 0.6 per cent carbon in solution, as in this instance, gives rise to the condition that only a small portion of Beta iron, if any, is formed prior to the merging of A_2 and A_1, and therefore the A_2 transformation is not evident.

The slight evolution of heat shown at 735 degrees Cent. (1350 degrees Fahr.) is due to the separation of Alpha iron. This separation continues until the solid solution composition attains that of the cementite eutectoid, at which time the temperature has fallen to 715 degrees Cent. (1320 degrees Fahr.). Here the formation of pearlite results in the pronounced heat evolution shown.

On the second heating the Ac_2 transformation is again apparent at 760 degrees Cent. (1400 degrees Fahr.), followed by the swingback mentioned previously. This swingback is cut short by the large heat absorption incident to the absorption of pearlite (or the Ac_1 transformation). The pearlite is that which was formed on the initial heating and which failed to graphitize on cooling. The location of Ac_1 above Ac_2 in this case is an instance of the lagging action previously mentioned. The lack of an evident heat absorption due to the iron carbon eutectoid on this second heating is probably due to its being completely masked by the absorption due to pearlite, and more particularly due to the fact that only a small amount of carbon and Beta iron enter solution at this point on the second heating. Subsequent heatings and coolings from this stage are simply repetitions of these actions.

The facts presented in the above discussion of the initial heating curve indicates that the iron-carbon eutectoid is in the neighborhood of 800 degrees Cent. (1470 degrees Fahr.). Since the rate of heating used in determining this curve and the tendency of the iron-carbon eutectoid transition to lag is not known, these data allow only an approximate

location of the eutectoid. The data presented in the following tables indicate that the iron-carbon eutectoid does lag and that it really lies somewhat lower than 800 degrees Cent. (1470 degrees Fahr.)

Table 1 (a and b), taken from the paper of Schwartz and coworkers, contains the data on the solubility of carbon in iron obtained under conditions which should produce equilibrium. Table 1 (a) represents the percentage of combined carbon present in a white iron sample heated to the temperature shown for periods ranging from 100

Table I

Solubility of Carbon in the Stable System

(From Schwartz)

(a) Beginning with hard iron

Temperature Degrees Centigrade	Per cent Combined Carbon	Decrease in Combined Carbon Per Cent	During last hours
740	0.08	0.00	144
750	0.12	0.00	72
775	0.57	0.09	96
790	0.78	0.04	96
790	0.66	0.05	96
825	0.68	—0.02	96
840	0.81	—0.02	96
850	0.73	0.01	72
950	1.10	Same time as 850 degrees Cent. equilibrium, graphite burned down to 0.12 per cent	

(b) Beginning with Annealed Iron

Temperature Degrees Centigrade	Per Cent Combined Carbon	Increase in Combined Carbon Per Cent	During last hours
740	0.05	—0.05	4
750	0.03	—0.04	4
780	0.56	0.27	5
1100	1.75	0.06	¼
		Graphite exhausted to 0.01 per cent	

to 300 hours. As a criterion of the attainment of equilibrium a check specimen was held at temperature for about 100 hours additional. Graphitization was initiated at temperatures of 900 to 1000 degrees Cent. (1652 to 1832 degrees Fahr.) in each case. Table 1 (b) represents the percentage of combined carbon present in a malleable iron sample which has been brought to the temperature shown and held at temperatures for the times shown. A check specimen was also used in this case. The values in both (a) and (b) of Table 1 undoubtedly represent equilibrium values, within the limits of accuracy of the methods used in determining combined carbon. We call attention to a variation of 0.12 per cent carbon on identical specimens treated at 790 degrees Cent.

It is to be noted that in Table I (a) there is a sharp decrease in combined carbon from 775 to 750 degrees Cent. (1427 to 1382 degrees Fahr.). In Table I (b) there is the same order of increase of combined carbon between 750 and 780 degrees Cent. (1382 and 1436 degrees Fahr.). It is to be noted that holding a specimen of malleable at any temperature below 750 degrees Cent. (1382 degrees Fahr.) does not cause a formation of Fe_3C, but that at a temperature lying between 750 and 780 degrees Cent. (1382 and 1436 degrees Fahr.) the combination of carbon and iron occurs abruptly. In like manner, it is noted that holding white iron at a temperature above 780 degrees Cent. (1436 degrees Fahr.) leaves at least as much as 0.56 per cent carbon in the combined form. At some temperature between 780 and 750 degrees

Cent. (1436 and 1382 degrees Fahr.) graphitization becomes practically complete. This evidence indicates very strongly the existence of a carbon-iron eutectoid at some point within this temperature interval corresponding to a carbon solubility content which is 0.56 per cent plus or minus the error of the carbon determination. It is to be regretted that such wide temperature intervals in this particularly interesting range were used.

We present further, Fig. 2, also taken from the paper already cited. They state—"if a completely graphitized specimen is heated to successively higher temperatures and cooled fairly rapidly after each

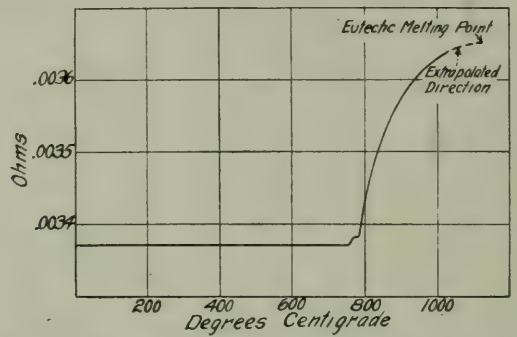


Fig. 2—Resistance at 22 Degrees Cent. of Malleable Iron After Cooling Rapidly from Various Temperatures. (Schwartz)

heating, the Ac_1 (stable) point should be indicated by a permanent change in resistance." Fig. 2 plots the results of such an experiment. Since nothing definite is known as to the rates of heating and cooling, or the length of time held at heat, we would only call attention to the fact that a rapid change in the electrical resistance occurs between 760 and 780 degrees Cent. (1400 and 1436 degrees Fahr.). This again suggests a carbon-iron eutectoid located somewhere between these temperature ranges. Due to our noting the uncertainty of some 30 degrees Cent., and some 0.2 per cent carbon in the location of the iron-carbon eutectoid according to the data presented, an investigation to accurately determine its location was undertaken in this laboratory by Messrs. H. E. Flanders and E. E. Moore. The results of this investigation will be ready for publication soon.

In addition, we wish to refer to the well known paper, "The Range of Solidification and the Critical Ranges of Iron Carbon Alloys," by Carpenter and Keeling[5]. The constitutional diagram resulting from their work is shown in Fig. 3. No interpretation of the significance of the points ranging across the diagram at temperatures of 775 to 800 degrees Cent. (1427 to 1472 degrees Fahr.) has to our knowledge ever been made. It is strongly suggested that the heat effects noted were due to the initiation of separation of Beta iron at the iron-carbon eutectoid, with or without the simultaneous separation of graphite. This series of points should not be confused with the Beta iron transformation occurring at the temperature A_2. It is to be noted in Fig. 3 that there is a sharp break of some 25 degrees Cent. in the temperature at which

5. *Journal* of the Iron and Steel Institute (British), No. 1, 1904.

these heat effects are noted between a carbon concentration of 0.4 and 0.6 per cent.

Carpenter and Keeling state that in obtaining their cooling curves the specimens were treated as follows: They were heated to a high temperature approaching that of incipient fusion in about 1½ hours, were there held for approximately ½ hour and were then cooled to 500 degrees Cent. (932 degrees Fahr.). This required an additional time of 1 hour and 20 minutes. To our knowledge no one has presented data as to the rate of graphitization at high temperature of *pure* iron car-

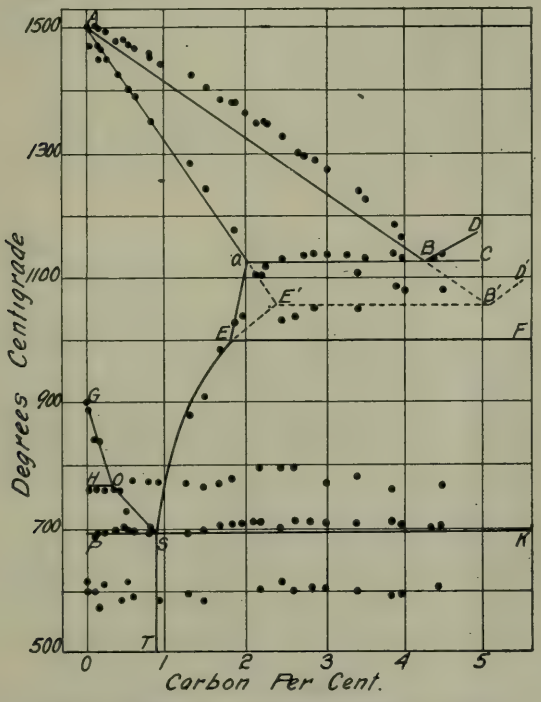


Fig. 3—Carpenter and Keeling's Diagram. (Sauveur.)

bon alloys such as here used. It is known, however, that white cast iron, as well as commercial high carbon steels, when cooled from high temperatures in small laboratory furnaces which reduce the temperature to below the critical in 1½ to 2 hours, results in typical bull's-eye structure; i. e., in partial graphitization at or near the eutectoid point.

The fact that this series of points ranges across the diagram at a temperature so distinctly above that of the Beta transformation that it suggests the presence of an iron-carbon eutectoid at this temperature. This would place the eutectoid at approximately 780 degrees Cent. (1436 degrees Fahr.) in pure iron carbon alloys. Having no knowledge of the effects of alloying constituents on the location of the iron-carbon eutectoid, we refrain from drawing any conclusions from the close agreement between its location in white iron and Carpenter and Keeling's specimens which were of considerable purity. We wish to point out here that attributing the heat effects noted by Carpenter and Keeling at 800

degrees Cent. (1472 degrees Fahr.) to the presence of a carbon-iron eutectoid demands very much more rapid rates of graphitization in these purer iron-carbon alloys than are encountered in the graphitization of white iron, since Carpenter and Keeling used such rapid cooling rates.

It seems probable, in the light of this reasoning, that a specimen of any carbon content, if cooled slowly from a high temperature to the temperature of the carbon-iron eutectoid and there held while sufficient heat was extracted, would completely graphitize. The evidence seems

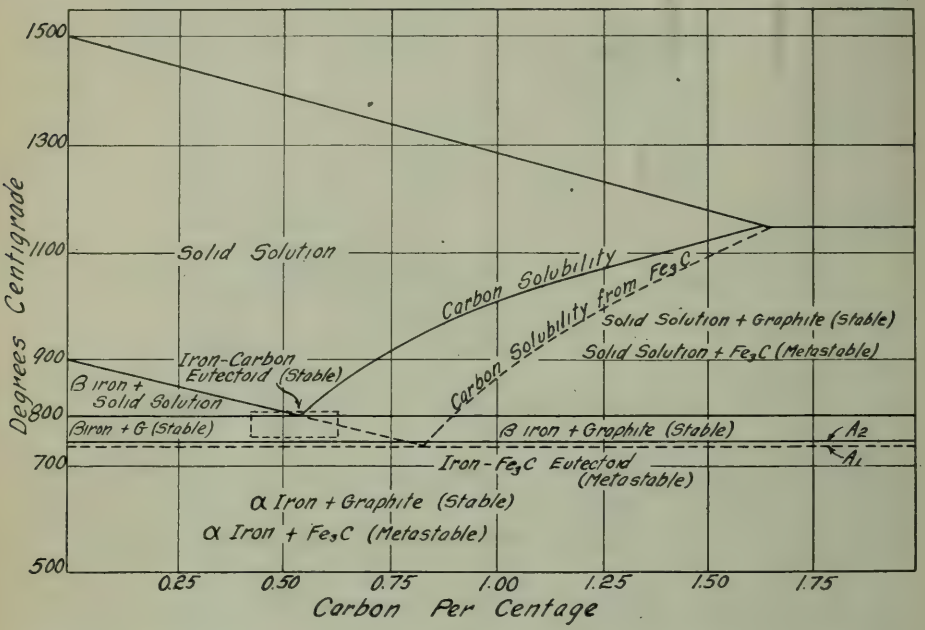


Fig. 4—Equilibrium Diagram for Iron-Carbon Alloys of Commercial White Cast Iron Composition.

to indicate that partial graphitization is actually taking place in specimens of 0.6 per cent carbon or more. That partial graphitization also took place in specimens of lower than 0.6 per cent carbon concentration, but that the heat effect was masked by the close proximity of the A_2 change, is also possible. The heat effect would, of course, be less intense as the carbon taking part in the action became less. It is to be expected that graphitization of steels above 0.6 per cent carbon would take place more readily since the stable form of carbon would be present to act as a seeding agent at the time the eutectoid was reached.

The location of the iron-carbon eutectoid in pure alloys, together with the rates of graphitization in these alloys, is now being made the subject of an extensive investigation by Waite P. Fishel in these laboratories.

The preceding discussion naturally leads to a conception of the equilibrium diagram for compositions ordinarily used in white cast iron as shown in Fig. 4. The conditions of stable equilibrium are indicated by the solid lines; those for metastable equilibrium are shown

by broken lines. The uncertainty in the location of the iron-carbon eutectoid is shown by the rectangle which surrounds it. The fields and lines on the diagram are fully labelled and are self-explanatory.

It was pointed out in our previous paper that in case there was but one solid solution; namely, that of carbon in Gamma iron, the iron-carbon eutectoid must be located at the intersection of the carbon solubility line with the A_3 or the $A_{2\text{-}3}$ lines. The results of X-ray work seem to establish beyond doubt that there is but the one solid solution. We, accordingly, have located the iron-carbon eutectoid within the rectangle as shown; i. e., within the range of 780 to 800 degrees Cent. (1432 to 1472 degrees Fahr.) for temperature, and at approximately 0.56 per cent carbon.

It has been the idea of the writers that the behavior of cast iron and steel will be found to be fundamentally the same, though many theoretical discussions which have appeared would lead one to believe otherwise. It is expected that work now in progress in this laboratory, to which we have already referred, will justify the presentation of an equilibrium diagram for steel which will be very similar to this one.

Discussion of Paper By H. A. Schwartz

The explanation by Hayes and Diederichs of the peak of 760 degrees Cent. (1400 degrees Fahr.) as being A_2 depressed below A_1 is, in the writer's opinion correct. Data more recently obtained in this laboratory on alloys of intermediate compositions seem to have yielded a progressive series of figures connecting known A_2 points with this point. Magnetometric investigations would be desirable, but would probably confirm the conclusion reached by the authors.

The writer, is, however, not in agreement with the interpretation of his own data placing Ac_1 at 800 degrees Cent. (1472 degrees Fahr.). This is the termination of the reaction which began at the break in temperature at just under 1450 degrees Fahr., say 785 degrees Cent., where resolution of carbon began. This is confirmed by the authors' Fig. 2 (Fig. 4 of our publication) showing a permanent resistance change at 760 to 775 degrees Cent., (1400 to 1427 degrees Fahr.). The use of the break in a differential temperature curve as defining the location of the critical point is in conformity with the views of Dr. H. M. Howe.

The discrepancy between the fourth and fifth results in Table I (a) is not, as Hayes and Diederichs believe, a lack of agreement between results under identical experimental conditions. In both cases the reaction is still proceeding at the rate of 0.04 and 0.05 per cent graphite in the last 96 hours. This was assumed to mark the completion of the reaction in line 4. Since the result was apparently erratic, the experiment was repeated using a longer time with the result shown in line 5.

It has been pointed out by Howe[1] that under the circumstances of the experiment the lowest trustworthy value of "combined" carbon marks the best approximation of the solubility. The above explanation might have been included in the writer's original publication, but was

1. *Transactions* of the American Institute of Mechanical Engineers. Vol. XXXIX, page 37.

omitted in the interests of brevity. It is here included since it may apparently be a source of confusion.

The analytical precision of our combined carbon data is probably better than 0.05 per cent; perhaps 0.02 per cent, and the true values of combined carbon can not be higher than the correct analytical values.

The assumption that the A_{tm} line and the A_1 stable line intersect on the usual A_{2-3} is based on the assumption that the A_{2-3} line is the same in both systems. However, plausible this postulate may be, we can not accept it unproven. Work is approaching completion under the writer's supervision calculated to cast light upon this point. For the present it will suffice to point out that Guillet and Portevin[2] recognize a possible difference.

Since the publicaton of our data we have read the earlier work of Ruer[3] which confirms our conclusions regarding the approximate spread between A_1 stable and metastable, and shows a much smaller divergence than that assumed by Hayes and Diederichs in their Fig. 4.

Authors' Reply to Mr. Schwartz's Discussion

The authors note that Mr. Schwartz agrees with their interpretation of the thermal data as it affects the A_2 and A_1 points.

In regard to the exact location of the A_1 point on heating, the authors have no reason to take issue with Mr. Schwartz. In speaking of this point we use the following expression: "There is a marked swingback immediately after this (Ac_2) change is completed. The second absorption which reaches *a maximum* at 800 degrees Cent. (1472 degrees Fahr.) is due to the simultaneous solution of Beta iron and carbon and is, therefore, the carbon-iron eutectoid."

We wish to state that we recognize in this statement that the absorption of heat due to the iron-carbon eutectoid set in at some lower temperature than 800 degrees Cent. (1472 degrees Fahr.) In making the statement "—and is, therefore, the carbon-iron eutectoid on heating," the authors' intent was to identify the iron-carbon eutectoid with the break in this heating curve, and not to give the impression that this was the temperature of the carbon-iron eutectoid. Further on in the paper we state "The data presented in the following tables indicate that the iron-carbon eutectoid does lag and that it really lies somewhat lower than 800 degrees Cent." It was due to lack of sufficiently definite information in regard both to the temperature and the carbon content of the solid solution in equilibrium at the carbon-iron eutectoid that the authors inserted the broken line rectangle in their diagram. This rectangle shows its location is indefinite by some 40 degrees Cent. In the light of Mr. Schwartz's explanation of his analytical data, it would now seem that the uncertainty regarding the carbon content of the eutectoid solid solution as shown by the rectangle is larger than need be.

In regard to the carbon-iron eutectoid being located at the intersection of the carbon solubility and the usual A_{2-3} lines, we wish to point out that all the phenomena noted, upon which we have data, can be explained without the assumption of two distinct solid solutions. There are numerous examples in liquid solutions where all the data indicates that the form of the solute as it exists in the solution, either

2. Metallography and Macrography, Fig. 218.
3. Zeit. Anorg. Chem., 117-4, page 249.

from metastable forms or from stable forms, is identical, differing only in the fact that the concentration corresponding to saturated solution from the metastable form is greater than the concentration of that derived from the stable form. In the case under discussion the metastable form (Fe_3C) also causes higher concentrations.

We wish to thank Mr. Schwartz for calling our attention to Ruer's article. After a careful study of this paper we feel that considerable additional experimental data will be required to justify Ruer's conclusion that the second break in his heating curves represents the iron-carbon eutectoid. It seems very possible to the writers that this second break marks the completion of absorbtion of alpha iron.

We would point out further that Ruer's data was obtained from pure iron-carbon alloys and that our work deals with white iron compositions. It is possible that in the two types of metal corresponding points do not agree.

METALLURGY IN THE MODERN SHOP

By M. H. Medwedeff

THE term metallurgy in its broad significance relates to the fundamental and accumulated knowledge dealing with the manufacture and fabrication of metals. In the case of steel, we might start with the reduction of the iron from its ores, the refining of the iron with its subsequent conversion into steel by various processes including the Bessemer, the open-hearth, the crucible or electric furnace methods; and finally its fabrication into billets, bars, rods, plates, etc., which are the raw materials with which the user of steel begins in the manufacture of his product, be it machinery, tools, automobile parts or the innumerable products of which steel forms an important part.

In this era of specialization, the practice of metallurgy seems to be divided into two distinct fields; that as applied to the manufacture of metal, and that as applied in their industrial uses, of fabrication in finished or semi-finished products. The manufacturing metallurgist deals with studying melting practices, developing formulas for the composition of his metals or solving difficulties arising in the mill, such as production of sound steel, splitting of billets in the blooming mill, etc. The metallurgist in the service of the consumer deals with the problems arising in the uses of these materials. We will confine these remarks to the latter field and particularly to steel, the metal in which most of us are interested.

Metallurgy in the shop deals with the physical conditions of metals and their behavior under the varying conditions of mechanical working, hot or cold, such as forging, punching, pressing, machining and heat treating. The master mechanic or "the man at the fire", may truly be experts in their lines, the first, having complete knowledge and experience in the design and operation of machines or production methods, the second with an experienced hand and eye in successfully heat treating a routine product or tools of well known "brands of steel". But when things go wrong in production processes, resulting in a sudden slackening in production or increased spoilage of work, due to causes mystifying to the mechanical department, a metallurgical investigation may easily locate the trouble. The investigation may disclose the fact that the material is too hard to machine under normal operating conditions of the equipment. The metallurgist may recommend that changes be made in the processing of the steel to put it into the physical condition suitable for the respective operating conditions, but where conditions permit it may be necessary to change cutting speeds. The changing of machine-tool speeds, however, affects very materially the production of a shop. Metallurgists are not always taken into the confidence of the designing engineer, and frequently materials are specified for manufacturing parts, while being suitable, yet may prove to cause manufacturing difficulties. An example of this might be the use of very low carbon steel for parts requiring considerable machining, resulting in the tearing of the work and the necessity for frequent regrinding of tools. In this case it becomes necessary to change the material. Or again a material is specified for cold working operations, such as punch pressing, and it is found that considerable cracking occurs due to the steel being too high in carbon. These points are given as examples to illustrate the application of metallurgy to practice.

A paper presented before a meeting of the Society. The author M. H. Medwedeff is chemist and metallurgist with the Wyoming Shovel Works, Wyoming, Pa.

Familiarity With Shop Practice Essential

The efficient metallurgist should be familiar with shop practice. He need not concern himself with the arrangement of machinery and mechanical details, but he should be familiar with performance of tools and cutting speeds. This would enable him to render effective service in machining difficulties or spoilage of cutting tools. This is of special importance in new organizations with new equipment where in spite of expert operating personell troubles arise which only the application of sound metallurgical knowledge can overcome. The writer has in mind an instance, an installation of trimming machines, where a grade of steel was selected, which was entirely unsuited for the operating conditions, and resulted in frequent failure of tools and otherwise spoiling the work. The steel salesman, who is seldom a metallurgist, when called upon in this case, was perforce, biased and was inclined to place the blame on conditions other than the fitness of the steel he furnished for this particular job. Somehow concerns employing metallurgists, either in their laboratories or as active heads of their heat treating departments, do not look to them for such service. It is up to the metallurgist to make his presence felt by unobtrusively working himself into such service so that the operating department will come to him for help on all such occasions.

We have spoken so far of metallurgical service in an advisory capacity, as an active aid to the man at the machine. It seeks to correct operating troubles due to physical conditions of the material used or the tools employed. Metallurgical service is however applied directly in processing the finished or unfinished steel products. Metallurgical knowledge dictates the annealing temperatures for the raw product, or the hardening and tempering temperatures for the finished or semifinished product.

The "man at the fire" may indeed be a skilled workman and successfully harden intricately designed tools or parts. But when things go wrong with the "man at the fire", and they often do, it is the man with the knowledge of "calescence, pearlite, cementite and pyrometers, etc.' who comes to the rescue. In the years past, small account was taken of the spoilage in the heat-treating shop, it was considered a part of the days work and usually the steel was blamed. Today scientific knowledge lends its aid to the practical heat treater in minimizing spoilage. Scientific control seeks to prevent the errors of "the man at the fire". The practical heat treater has obtained wonderful results considering his lack of fundamental knowledge dealing with the properties of steel. The intelligent worker, however, is today anxious to make up this defect by burning the midnight oil and studying the very excellent books available on the subject of the heat treatment of steel. He has become much interested in the story the microscope tells when he strikes a snag, and in proportion to his interest in fundamental knowledge, his suspicion of the man with the knowledge of "calescence" diminishes and he becomes a genuine asset.

Metallurgy seeks to cooperate with the designing engineer in working out the most suitable materials for the design of the parts of his machine. The engineer calculates the strength that operating conditions will demand of the individual parts of the machine he is developing, and the metallurgist works out the physical properties of these materials and imparts to them the strength that engineering practice demands.

A Study of Typical Failures Important

Perhaps the greatest service the metallurgist renders is in the study

of periodic or chronic failures of parts in service. A study of failures in service of automobile parts furnishes us an excellent example because the automobile embraces most of the important uses of steel under the most varied conditions. In studying these failures we are thus enabled to apply rational cures and avoid the recurrence of such failures. This is of particular importance in developing a new machine. Experimental trials may develop chronic failure, in a particular part. As an example we will take a particular case, that of repeated failures of crankshafts which failed at nearly the same place each time. The failure may have been due to either faulty design, bad workmanship, faulty heat treatment or the selection of the wrong material for the service requirements of this part. Just a little thought will dismiss the possibility of faulty heat treatment, as it is not likely that failure would occur in the same place, even if this should have been the cause of failure. Examination of the fractured surface showed that the heat treatment had been uniform and the physical tests revealed the desired physical properties. The workmanship of the part itself as nearly perfect as commercial practice permits. We then have two considerations left, either faulty design or the selection of the wrong material for the part. A study of the fracture throws considerable light on the subject. If the fracture is smooth over the greater portion of its area, showing concentric rings, and the steel is rougher over one portion than over the rest of it, it indicates a typical fatigue failure. Failure in these pieces occured as a result of either a large number of stresses applied intermittently in one direction or alternately in opposite directions. When strains are large and approach the elastic limit, failure is rapid, but when stresses are relatively small, failure is postponed indefinitely. However, it is not the purpose of this paper to enter into a discussion of the mechanism of fatigue failures. Having established that failure was due to fatigue of the steel we must now suggest a cure to prevent its occurrence. Obviously two remedies suggest themselves, we must either redesign the part and give it a larger cross section to withstand the load or raise the elastic limit so that while the stress is the same it will be considerably below the elastic limit. Our choice will be governed by practical shop considerations. The latter necessitates the selection of a higher grade material and is apt to increase manufacturing costs due to slowing up in machining operation. If conditions permit, the design of the part is usually changed.

Sometimes parts fail due entirely to faulty design in not taking into consideration metallurgical details. As an illustration of this we might mention failures in steering-knuckles. These sometimes fail at the junction of the vertical member with the spindle. This is frequently due to an insufficient fillet. Sometimes these are due to improper material or again to improper specification of physical properties for the part.

One can go on indefinitely and enumerate investigation and studies of failures and their remedies, based on co-ordinating highly developed metallurgical knowledge with sound engineering practice. These few cases have been mentioned, not as a plea for the metallurgist in the shop, but for the larger use and appreciation of the potentialities of metallurgical service, and if these remarks serve their purpose, the writer will have been well repaid.

DELAYED CRYSTALLIZATION IN THE CARBON STEELS—THE FORMATION OF PEARLITE, TROOSTITE, AND MARTENSITE

By A. F. Hallimond

Abstract

The paper deals with the application of the supersaturation theory of steel. A summary of recent researches on delayed crystallization and inoculation is first given, after which the origin of pearlite, troostite, and martensite is discussed. The area below the eutectoid point, common to the metastable ranges for cementite and ferrite, is termed the cutectoid area, and indicates those conditions under which the growth of pearlite can occur. The causes that determine the spacing of pearlite are described. Martensite is regarded as a labile shower of a-ferrite and troostite as a labile shower of cementite; in the latter case the appearance of the cementite is quickly followed by the growth of a-ferrite due to inoculation by the cementite at a relatively high temperature.

THE equilibrium relations of ferrite, cementite, and austenite present, as is well known, a close analogy with those of two mutually insoluble solids crystallizing from a liquid solution. This analogy has provided a convenient basis for the description of the microstructures exhibited by those constituents in slowly cooled steels. Of recent years, however, the active prosecution of research on quenching has rendered it necessary to discuss the growth of structures, such as martensite and troosite, that have no counterpart among those formed by crystallization from a liquid under approximately reversible or "equilibrium" conditions. In such cases it is necessary to take into account the principles governing "delayed crystallization"; these have been established chiefly as the result of a series of researches by Miers, Barker, and other workers during the last twenty years, and have not yet had time to receive full treatment in most text-books. The author has therefore ventured, before dealing with the carbon steels, to give in the first part of this paper a somewhat more detailed summary of that work than would otherwise have been necessary. In the second part an attempt has been made to indicate the lines on which these principles may be applied to account for the structures developed in carbon steels; the accurate thermal and other investigations required have recently been made available in the detailed researches of Portevin and others, and reference has been made to this work in discussing the delayed critical points and corresponding structures in terms of the supersaturation theory.

The view that the doubling of the critical points might be attributable to delayed crystallization is not new, for this was already suggested by Miers in 1907[3]* as a possible explanation of the doubled critical points observed by Roberts-Austen in certain alloys during solidification. Moreover, in the same paper, which deals with the freezing of a binary mixture, the conditions governing the appearance of crystals of each constituent are defined, and the

3* The small figures appearing after the names of authors or points of reference, refer to the bibliography appended to this paper.

A paper presented before the Annual Meeting of the Iron and Steel Institute, May 1922.

possible variations in the order of crystallization indicated. Again, of recent years, Stead, Portevin[26], and other workers have used the principle of inoculation by more or less "isomorphous" nuclei to account for the premature precipitation of cementite and the growth of ferrite in the neighborhood of inclusions. Finally Portevin[27] has given an outline of certain continental work on delayed crystallization, with reference to the devitrification of glasses, but this does not include any account of the English work above mentioned. No general application to the crystallization of steel has so far been given, and the present account has therefore been prepared in the hope of stimulating interest, and of providing material for the discussion of these questions. The development of a systematic treatment of this subject seems a necessary preliminary to the microstructural investigation of the special steels.

General Principles

In considering the influence of the rate of cooling upon microstructure, three main principles must be taken into account. The first concerns the existence, below the ordinary solubility curve for each constituent, of a range of temperature and concentration within which crystallization is only initiated upon the introduction of a suitable nucleus. The second is that the rate of growth of a crystal at first increases as the temperature falls below that of equilibrium, and then diminishes when a certain degree of supercooling is exceeded. The third is that the redistribution of heat and of dissolved matter, consequent on and essential to solidification at the surface of a growing crystal, is governed by gradients of temperature and concentration which depend in their turn upon the respective coefficients of heat conductivity and of diffusion.

Recent Researches on Delayed Crystallization and Inoculation

The Supersolubility Curve

The fact that many carefully supercooled solutions would only crystallize on the introduction of a nucleus has long been recognized.[11] Measurements by Tammann[12] indicated that the period of duration of this condition diminished as the temperature at which the solution was held fell below the normal saturation point, at which solid and liquid can permanently coexist. The tendency to crystallize* (like the crystallization-velocity) increased at first with diminishing temperature and then again diminshed, so that a fused substance cooled through ths range with sufficient speed remained as an amorphous solid, *i. e.*, a "glass." With moderate supercooling the nuclei appear rarely, or, as was shown by Miers[1] and Ostwald[11], not at all within a period of many weeks' duration. Ostwald proposed the terms *metastable* for this condition and *labile* for that induced by a greater degree of supercooling, in which crystallization, when once initiated, extends rapidly throughout the mass with the development of a characteristic shower of crystals. The metastable state was not at first regarded as being very sharply separated from the labile, but the sharpness of the boundary in certain cases was recognized by Ostwald.

As the result of extensive researches by Miers and his co-workers, the observation first recorded by him in 1906[1] has been fully verified in the case of numerous compounds and mixtures. It is possible, under suitable condi-

* Measured by the number of nuclei appearing in unit time in unit volume.

tions of experiment, to determine a sharply-defined boundary, termed the *supersaturation point,* between the metastable and the labile states, and a solution in a sealed tube may apparently persist indefinitely in the former condition, though a fall of a few degrees in temperature will at once cause the precipitation of the labile shower. Two standard methods are used in these researches: (*a*) The slow cooling of a liquid, covered if necessary with oil to prevent inoculation by dust in the air. At a well-defined temperature the substance in supersaturation crystallizes in numerous small crystals, termed the *labile shower.* With many liquids (*c. g.,* sodium chlorate solution) mechanical stirring is necessary before the shower will appear. The changes in concentration are measured by means of the refractive index, determined by total reflection in a glass prism immersed in the liquid[10]; when the shower appears the combined actions of the fall in concentration and the heat evolved cause a sharp diminution of the refractive index. (*b*) The second method consists in allowing the liquid to cool slowly in sealed glass tubes; with constant shaking many substances crystallize in a shower at the supersaturation point, but in certain cases it was necessary to place pieces of glass or heavy minerals such as corundum, garnets, etc., in the tube to increase the friction[1]: this was particularly the case with the more viscous liquids. The results of the two methods are concordant, and when the supersaturation points for various concentrations are plotted upon the ordinary freezing-point or solubility diagram for a mixture or solution they are found to lie on a second curve, termed the *supersolubility curve,* which lies below the ordinary equilibrium curve and follows a similar course, but is not necessarily strictly parallel to it. The space between the two curves represents the metastable state, that below the supersolubility curve, the labile state. A thin shower sometimes appears when a solution is shaken in the metastable state, owing probably to chance inoculation. If not shaken or stirred, the more viscous solution can be brought far into the labile state without the appearance of a shower.

The extent of the metastable range varies rather widely for different substances. For cæsium nitrate in aqueous solution it is practically zero[4], for ice forming in salt solutions it is usually 1 or 2 degrees Cent., while for $Na_2SO_3.7H_2O$ in aqueous solution it reaches 30 degrees Cent[8].

Miers indicates[3] the importance of these effects in determining structures. If the supersolubility curves of the two constituents are plotted on the diagram for a binary mixture having a eutectic point, the two curves intersect at a point termed the *hypereutectic point.* The conditions of crystallization in such a simple mixture were investigated for mixtures of salol with betol[3]; multiple critical points were observed in the neighborhood of the eutectic, and reference is made to the bearing of the experiments on the genesis of eutectic structures.

Following the same line of investigation a series of researches were made upon systems of which the components crystallized in a continuous series of mixed crystals[5], and in a series of mixed crystals forming a eutectic with the other constituent[9]. The supersolubility curves were determined and in some cases the composition of the first mixed crystals formed at the beginning of the labile shower was ascertained. These differed in composition from the liquid, even when the supersaturation point lay below the solidus curve. Viscosity must here play a considerable part, however, in limiting the selective crystallization of material, and the present observation does not seem essentially inconsistent with the observation of Day and Allen that the

viscous felspar melts, when crystallized below the solidus, yield crystals of the same composition as the liquid and not zoned.

The remaining references in this section relate to investigations, mainly on dissolved salts, in all of which satisfactory values for the supersolubility curve were obtained by the methods described above.

Inoculation

When the solution of a substance is in the metastable state, crystallization can be initiated at the surface of a suitable nucleus introduced from without or already present in the liquid. This nucleus must usually be a crystalline particle, either of the substance itself, or of an "isomorphous" body. The interpretation of the latter term has been much discussed, for detailed measurements show that, even in the case of crystals with close structural similarity, the actual dimensions of the space-lattice are characteristic for each substance; both angles and linear dimensions may vary widely within the same "isomorphous" group[32].

The nature of isomorphism and the conditions for parallel growth between different members of certain isomorphous series have been investigated by Barker[13, 16, 18]. The method of experiment was extremely simple, a drop of solution of one salt being placed on a fresh cleavage or other surface of the crystal on which parallel growth might be expected to occur. Three types of growth were recorded: (1) *Zonal growth,* by the deposition of a uniform crystalline layer over the whole surface of the inoculating crystal. (2) *Parallel growth,* by the deposition of many small separate crystals in parallel position, scattered over the surface of the inoculating crystal. (3) *Irregular growth* of many small separate crystals on the surface of the inoculating body, but not in parallel position. The first is limited to pairs of substances with very nearly identical molecular volume; the second occurs between the majority of isomorphous substances, while the third is found in those cases where the two crystals differ most widely in molecular volume. An idea of the degree of similarity necessary for parallel growth between halide salts of the alkali metals[16] may be formed from one of the extreme cases, in which RbBr, with a molecular volume of 49.30, yielded parallel growths on KCl which has the molecular volume 37.49.

The property of forming parallel growths is exhibited by many pairs of substances that are not capable of forming mixed crystals. It seems to be mainly dependent on the equality of molecular volume, or perhaps even on the equality of spacing in one or two directions only, for this would appear to be the determining factor in many cases of regular growth among minerals, in which crystals are arranged with such directions parallel.

As is well known, sodium nitrate crystallizes in parallel on the cleavage surface of a piece of calcite. This has been examined, with many other similar cases, by Barker[15], and also by Miers and Chevalier [14], and by Beilby [19]. In the metastable state the solution deposited parallel crystals, in the labile state the growth was irregular. The subject was taken up by Kreutz[21], who showed that sodium nitrate formed parallel growths on calcite and barytocalcite; lithium nitrate, on the other hand, would not make parallel growth on calcite, but readily did so on the isomorphous carbonates of manganese and iron. Comparison of the densities of these substances indicated again that similarity of volume is the chief factor and not similarity of crystal angles. A further interesting fact is observed by Barker[22], that calcite will always induce the precipitation of rhombohedral potassium nitrate, but that the crystals so formed are not in parallel position,

Chevalier[15] observed that different minerals, especially galena, induced crystallization in potash alum solutions at characteristic temperatures, while glass also acted as a nucleus, but only in the labile state.

In the light of the observations of Miers and Chevalier it seems legitimate to assume that in Barker's experiments the parallel growths represent, in the main, deposition from the metastable state and the irregular growths deposition from the labile state. We have, therefore, a range of conditions extending from a complete structural similarity that yields zonal growth as soon as the equilibrium curve is passed, to the non-isomorphous structures that usually only affect the solution when it has entered the labile state. For each foreign substance there will be a characteristic temperature at which it is capable of initiating crystal growth.

It has been recognized, by Miers and other workers with the same methods, that the determination of the supersaturation point may be affected by inoculation. The glass sides of the vessel, the surface of the liquid, and the platinum stirrer are all potential sources of inoculation, but it is shown that the point is but little affected by the conditions of experiment[1, 7]. The addition of mineral crystals to the tube experiments is apparently more dangerous, and Jones[4] considers that differences in the determined supersaturation points for ice are due to the use of garnets in the tubes. It is even possible for glass to induce parallel growth; thus a drop of potassium nitrate melted under a coverglass on a microscope slide crystallizes with a granular structure in which the principal axis of each grain is nearly perpendicular to the cover-glass. Sometimes scattered, irregularly orientated grains are seen, and it seems clear that crystallization has then begun at a few nuclei, while with a further drop in temperature the remainder of the nitrate solidified in parallel growth on the glass.

The Time Element.—Even in the production of a labile shower, the number of nuclei formed is finite, and it must be recognized that the occurrence at a given point of the necessary condition for spontaneous crystallization or for inoculation is dependent upon the lapse of time; the probable explanation of this lies in the occurrence of deviations from the average state of a fluid in the manner indicated by the kinetic theory. Nevertheless, the probability of crystallization in many cases increases so rapidly that with falling temperature that the labile shower has the appearance of being instantaneous, while even the formation of scattered crystals on an inoculating surface is subject to definite limits. In both cases, however, the number of nuclei can be diminished by sufficiently rapid cooling; thus sharply defined points are characteristic of rapidly crystallizing bodies, and in cases where crystallization is particularly slow, as in glasses, the supersaturation point is represented by a range of temperature in which the number of nuclei appearing undergoes a rapid increase[12]. On the whole there seems ground for regarding the true supersaturation or inoculation point as a definite limiting temperature, above which crystallization will not occur even on indefinitely slow cooling.

Application to Crystallization in Solid Bodies Such as Steel

In steel, crystallization takes place obviously in the complete absence of stirring, the only analogue of this being violent mechanical working of the sample. The transport of material and of heat by convection and the introduction of nuclei from outside are alike eliminated. The supersaturation point, which is often only developed on vigorous stirring in fluid solutions, is therefore not necessarily developed at all in steel, and it is not per-

missible at once to identify the point at which any particular recalescence begins with the supersaturation point of Miers. With relatively slow cooling we are much more likely to encounter the specific inoculation points characteristic of the various crystals present, and of the intergranular surfaces; in the steels now under discussion it is an almost invariable rule that the grains of a new constituent originate at surfaces and not in the body of the austenite. The criterion of the supersaturation point, if present, is the appearance of a shower of small crystals; in two cases only does this occur in steel, namely, on the formation of troostite and of martensite. The temperatures of formation of these constituents are therefore taken to represent the supersaturation points of austenite with reference to cementite and *a*-ferrite respectively, and the remaining recalescence points are regarded as originating in inoculation, at specific temperatures, by the surfaces from which the new constituents begin to grow.

Linear Crystallization-Velocity and Crystal-Habit

The speed with which a growing crystal-face advances normal to itself is termed the linear crystallization-velocity. When a solution is only very slightly supersaturated the rate of crystal-growth is small, and the habit of most crystals tends to be compact and symmetrical. It is under these conditions that the external form can accommodate itself to the condition that the surface energy shall be a minimum. When the degree of supersaturation is greater it would appear that growth is controlled by two factors; the diffusion of material into the approximately saturated layer in contact with the growing face, and also a definite heterogenous reaction-velocity conditioning the deposition of material. The latter would seem often to be the principal determining factor in the resulting crystallization-velocty; it may vary widely for different modifications of the same substance, as with tridymite and cristobalite, and for different faces of the same crystal. The result of the latter difference is that a crystal growing in a supersaturated solution often exhibits a tendency to growth in certain directions only, so that the normal crystal-habit gives place to pronounced acicular or tabular growth.

It was shown by Tammann[12] that this crystallization-velocity at first increases as the supercooling increases, then remains constant, and finally diminishes more or less sharply with falling temperature, probably owing in the first place to the usual increase in speed of a reaction with departure from equilibrium, and in the second place to the increase of viscosity and diminution of reaction-velocity with falling temperature. The subject has been summarized from the crystallographic standpoint by Ritzel[29] and, from the standpoint of glass-making, by Portevin[27].

Diffusion of Heat and of Material

The continued growth of a crystal is conditional on the maintenance of a supply of material by diffusion, and on the dissipation of the latent heat developed in crystallization. In the case of a pure substance the former effect does not come into account, and Tammann regarded the above-mentioned increase in rate of crystallization with supercooling as due simply to the second cause; the latent heat developed on crystallization sufficed to raise the temperature at the growing surface to a point near the true solubility curve, and further growth only proceeded as heat diffused away to the cooler parts of the solution.

Steel represents a somewhat extreme case, in which the heat conductivity

of the metal is great, while the coefficient of diffusion of carbon in γ-iron can hardly be regarded as more than that of a salt in water. Crystal growth will therefore take place under relatively isothermal conditions as regards the interior of the steel, the temperature of the surface of a growing constituent differing but little from that in the interior of the grains. Crystallization thus proceeds at any moment at the temperature recorded pyrometrically for the mass of the steel.

The transition from approximately equilibrium crystallization to a condition in which the structures begin to show very definite evidence of incomplete adjustment in concentration during the range Ar3-Ar1, occurs in the neighborhood of the critical rate of quenching, as determined by Portevin in his work on the delayed critical points[28]. That author records that at rates of cooling which yielded troosite the free constituents still separated in the noneutectoid steels. With faster quenching the austenite areas fail to contract with separation of the free constituent, and the whole sample is obtained in the martensitic state. In ordinary slow-cooled steels, therefore, it must be admitted that the readjustment of concentration has time to proceed nearly to equilibrium, and that the composition of the austenite areas does not vary to any great degree from the center to the margin.

The laws governing the diffusion of material are analogous with those governing the diffusion of heat. The development of temperature gradients in cooling solids has recently been discussed mathematically by Williamson and Adams[30], and the analogy between concentration-and temperature-gradients is referred to by Bowen[31]. Detailed reference to this question will not, however, be required here, and it will suffice to refer to these recent publications.

Crystallization in Ordinary Carbon Steels

An endeavor will next be made to ascertain how far the crystallization of the ordinary steels can be explained in terms of the supersaturation theory outlined in the preceding sections. Fig. 1 represents part of the usual iron-carbon diagram, *oa, ob* are the equilibrium curves for *a*-ferrite and cementite in contact with austenite; they meet in *o,* the eutectoid point, at a temperature of about 725 degrees Cent. Below these curves have been represented various lines required by the supersaturation theory. *o'a'*, *o'b'* are the supersolubility curves below which martensite and, in part, troosite, are formed. The point *o'* is the hypereutectoid point (following the nomenclature of Miers[3]. The metastable range for *a*-ferrite lies between the lines *oa* and *o'a'*; that for cementite between the lines *ob* and *o'b'*. The areas below *o'a'* and *o'b'* are the labile regions for *a*-ferrite and cementite. In the area *opo'q* both *a*-ferrite and cementite are metastable; in the presence of nuclei both constituents will grow simultaneously, and so this area represents those temperatures and concentrations at which eutectoid structure can develop. It will, therefore, be termed the *eutectoid area. f*F represents the inoculation line at which nuclei of *a*-ferrite appear on the intergranular surfaces of austenite. *c*C is similarly the line at which nuclei of cementite appear on the austenite surfaces. These indicate the points at which the free constituents first crystallize in cooling samples. The remaining two points represent the temperatures C' at which cementite nuclei appear on the surface of free *a*-ferrite crystals, and F' at which *a*-ferrite nuclei appear on the surface of free cementite crystals. These are the temperatures at which the eutectoid crystallization begins in hypo and hyper-eutectoid steels.

All the points of delayed crystallization, especially those of inoculation,

are depressed with increasing speed of cooling. The values given in the diagram correspond roughly with those for small samples about 16 millimeters in diameter, and have been based on the critical points given by Portevin and Garvin[28].

Crystallization on Slow Cooling: Pearlite

(*a*) *Hypoeutectoid Steels.*—Let a medium carbon steel d_1 (Fig. 1) cool slowly until the ferrite line is passed. In the absence of nuclei no free ferrite will appear till a point f_1 is reached at which inoculation occurs on the intergranular surfaces of the austenite. This occurs at a temperature far above that at which shower-precipitation takes place. The ferrite separates at the grain-boundaries† with recalescence (Ar3,2), and the remaining austenite has the composition *g*. With further cooling the ferrite grows and the austenite reaches the eutectoid composition *o*, but in the absence of nuclei no precipitation occurs and the concentration continues to increase until a point C′ is reached at which cementite appears by inoculation on the ferrite surfaces. The interior of the austenite inevitably lags somewhat in composition below the surface, and so the state of the austenite grains is best represented by a horizontal line C′1. This is within the eutectoid area, and growth of pearlite at once sets in with recalescence. Provided the rate of cooling is not too slow, the steel remains below the line *oc*′ and continuous growth of grains of pearlite results. The temperature attained in the recalescence is from 690 to 700 degrees Cent., while the growth of pearlite originates at about 680 degrees Cent. This temperature is distinctly higher than the troostite recalescence point, and there is no reason to suppose that in slow cooling the margins of the austenite undergo a shower-precipitation, though this condition may be very nearly approached. In other words, the point C′ is within the metastable range and growth is initiated by inoculation.

(*b*) *Hypereutectoid Steels.*—Let steel d_2 (Fig. 1) cool slowly until the cementite line is passed. In the absence of nuclei precipitation will not begin until a point c_2 is reached at which free cementite grows by inoculation on the intergranular surfaces of the austenite. At this point the remaining austenite assumes the composition h_2 and, when the eutectoid temperature is reached, has the composition *o*. Ferrite does not appear until F′ is reached, at which *a*-ferrite appears at the cementite surfaces. Nuclei of both constituents being presented in the eutectoid area, growth of pearlite occurs with recalescence. The crystallization is initiated at about 665 to 675 degrees Cent., or at higher temperatures with slower cooling, and the recalescence point is about 710 degrees Cent. On account of the great steepness of the line *o*F′ the interior of the austenite has nearly eutectoid composition, and the temperature of eutectoid crystallization can consequently rise further toward the eutectoid point 725 degrees Cent., than in the hypoeutectoid steels.

(*c*) *Eutectoid Steels.*—It is clear that within a certain range of composition above and below the eutectoid point the austenite formed after separation of the free constituent will be at once in a condition for initiating the growth of pearlite at the points C′ and F′. Within this range there will be

† The symmetry of a crystal forming a liquid is determined by the structure of the crystal, but in the case of a crystal forming at the expense of another crystalline solid there is no reason to expect the form to depend on one body rather than on the other. In steel, in fact, both *a*-ferrite and cementite develop "along the cleavage-planes of the austenite," and their shape is determined to a great extent by the symmetry of the latter.

overlapping of the critical points, and a tendency to irregular distribution of the ferrite. The steels will all appear to consist almost entirely of pearlite.

The initiation of crystallization in eutectoid steels only occurs when the lines *f*F or *c*C are reached. The temperature at which recalescence begins will, therefore, here reach a minimum, but formation of pearlite will proceed freely when once started. For the same reason a steel somewhat below the eutectoid composition can the more easily be cooled out without the appearance of free ferrite or troostite[28].

(*d*) *Appearance of Marginal Carbide in Pearlite in Hypoeutectoid Steels.*—It will be observed that if the recalescence initiated at C′ carries the austenite to a state represented by a point above the line *o*C′, the growth of ferrite will cease, for the austenite is no longer metastable with respect to ferrite. Cementite, however, will continue to grow on existing nuclei. In the cases discussed above, the speed of cooling is assumed to be sufficient to keep the conditions below *o*C′; if, however, the austenite has attained the state C′ throughout, either by slow cooling as in a large casting, or by long diffusion in a small area between the points Ar3 and Ar1, as in a low-carbon steel, the recalescence will carry the temperature above *o*C′ and carbide alone will crystallize on the margins of the austenite. Meanwhile the interior will be brought back by diffusion and cooling to a point within the line *o*C′ but nearer *o*, and will crystallize as pearlite. Cementite margins of this nature are well known, and have been attributed to "divorce" of the pearlite, but this explanation fails to account for the relatively greater frequency of the effect in the low-carbon steels.

The Eutectoid Structures

In the preceding account two distinct types of pearlite formation have been indicated, occurring near the points F′ and C′, for hyper- and hypoeutectoid steels respectively. This corresponds, as above explained, with the well-known fact that the critical point is distinctly higher for the hypereutectoid steels than for those in which free cementite is not present.

The formation of eutectic structures was at first regarded by Miers as occurring in the neighborhood of the hypereutectic point. Sections of preparations formed under such conditions have, however, generally indicated a finely granular structure corresponding with shower-precipitation, and the characteristic interlocking of the constituents was rarely, if ever, obtained. It seems clear in the present case that the eutectoid structure is characteristic of growth in the metastable state, but at points which may lie very close to the equilibrium curves; the conditions for propagation of the structure being that the solution shall be metastable with respect to *both* constituents and that nuclei of both shall be present (*i.e.*, the representative point shall lie within the eutectic area *opo′q*.)

The removal of one constituent by crystallization at once leaves the other in excess. The precipitation of the latter is then accelerated and so the eutectic grain grows with a continuous boundary, even if the natural rates of crystal growth of the constituents differ considerably. If one constituent is present in predominant amount, the eutectic grains usually assume a crystalline form approximating to that of the dominant constituent. It is necessary to emphasize the fact that the eutectic structure has nothing in common with dendritic growth. The latter occurs in the lower part of the metastable range[15] and has a highly distorted crystal habit. The eutectic, on

the other hand, is formed at temperatures but little below equilibrium, and may have a quite normal crystal habit for the dominant constituent. In the eutectic the interfaces between the constituents are often irregular or are the nature of "combination-planes," while in free dendritic growths the outline is determined entirely by the symmetry of the one constituent concerned.

The form of the recalescence curve at Ar1 is extremely characteristic. It consists of a steep rise from the point of inoculation, followed by a period of constant temperature, after which cooling sets in as the crystallization is completed. It is most significant that when the rate of cooling is increased the temperature of the level part of the curve is depressed, although the constancy of temperature is still maintained[28]. The explanation of this is to be found in the fact that the rate of crystal growth increases as the temperature falls below equilibrium. This results in an increased rate of evolution of heat, and so far various rates of cooling corresponding temperatures exist at which the heat evolved in crystallization balances the heat removed by cooling and constancy of temperature results.

As is well known, the more rapid the cooling of a sample the finer the pearlite; fine pearlite must therefore be regarded as characteristic of rapid crystallization. It may be worth while to examine briefly the causes that determine the spacing of the pearlite lamellæ.

Every growing crystal is surrounded by a film in which the concentration varies quickly from approximate saturation at the growing surface to the condition of the surrounding liquid. The steepness of the gradient in this film depends on the coefficient of diffusion of the crystallizing substance. If two crystals approach close together they will compete for the dissolved material, and growth will diminish when they come within a range depending on the thickness of the surface layer. This is well seen when two dendrites meet in a crystallizing drop; growth ceases, and there remains a clear space of liquid between the crystals. There is thus a limit within which two crystals cannot grow rapidly side by side. If growth is slow, diffusion operates to a considerable distance and the interspace is wide, but if growth is rapid the crystals can approach more nearly together and the dendritic structure has a finer grain. Now in pearlite the exposed surface of each cementite lamella grows by diffusion from the surrounding austenite; round each lamella will be a saturated zone, and should two lamellæ approach too closely their growth will be arrested; if, on the other hand, the lamellæ are too far apart, the cementite in the intervening region must be deposited on a fresh nucleus or on branches from neighboring lamellæ. Thus for each condition of formation there will be a characteristic average spacing, which gets closer as the rate of growth increases.

Supersaturation Effects on Rapid Cooling: Martensite and Troostite

Three characteristic temperatures govern shower-precipitation in the labile state; they are: (1) The equilibrium point; (2) the supersaturation point at which the shower appears; (3) a point, or rather a range of temperature, below which crystal growth is completely arrested owing to viscosity or to lack of crystallization-velocity.

Recent researches have made it clear that martensite is a fine aggregate of *a*-ferrite crystals. The temperature at which this aggregate is formed, by a shower-precipitation, is determined as about 350 degrees Cent. for approximately eutectoid steel[28], and is the recalescence point Ar″. It has been

identified by Dejean[24] with the point Ar3, depressed by extremely rapid cooling. This view is opposed by Portevin[25], who regards it as a point of "labile equilibrium," between austenite and a labile solid solution of carbide in *a*-ferrite. In the following note it will be treated simply as a supersaturation point analogous with those observed in solutions in which spontaneous crystallization occurs without stirring.

Both Guillet and Portevin agree that the point rises with diminishing carbon content, so that the supersaturation curve *o'a'* will have a course

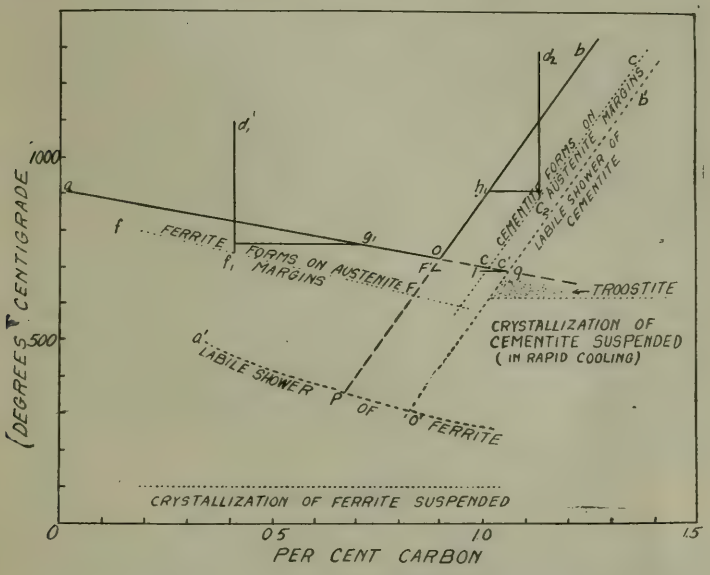


Fig. 1—Diagram to Illustrate Delayed Crystallization in ordinary Carbon Steels

Note.—In order to simplify the diagram, the ferrite curve is represented as a straight line and the temperatures on the cementite curve are greatly exaggerated. The gradients near the eutectoid point are approximately correct.

such as is shown in Fig. 1. The region of suspended crystallization sets in below 100 degrees Cent., beyond which austenite undergoes little, if any, decomposition. When once the shower has appeared the supersaturation curve has no significance; there is thus no corresponding critical change on tempering. The latter consists in the grain-growth of *a*-ferrite and in the agglomeration of carbide, hence the close resemblance between the course of tempering and that of grain-growth.

Troostite is encountered mainly in the higher carbon steels and in hypoeutectoid steels in which the austenite areas have approached eutectoid composition. On rapid cooling of the latter class the troostite appears only at the margins between the austenite and the ferrite while the interior passes into martensite. These grain-margins represent regions in which the carbon is most concentrated, and troostite therefore seems to be a constituent only obtainable in the neighborhood of the eutectoid composition**. The temperature of formation of troostite, Ar', varies from 665 degrees Cent. in a high-

** This refers only to the troostite formed in directly cooled steels, and not to the fine temper-structure also sometimes called by this name. In the same way "pearlite" is used with reference only to the eutectoid aggregate and not to any aggregate of cementite and ferrite, however derived.

carbon steel to 635 degrees Cent. on rapid cooling. Beyond this stage the critical rate of quenching is reached and the point is not further depressed but vanishes, its place being taken by Ar'' at 350 degrees Cent. with formation of martensite. The physical properties of troostite show that it is a mixture of α-ferrite and cementite[23].

The formation of troostite may be explained as follows: On the supersaturation theory, shower-precipitation of cementite will occur when a steel passes the line $o'b'$, the supersolubility curve for cementite. This curve, which will be roughly parallel with the equilibrium curve, is very steep, and so the low-carbon austenites can only yield martensite. A further restriction is, however, necessary; since Ar' cannot be depressed below 635 degrees Cent., it follows that at this temperature the range within which cementite cannot crystallize must supervene. The shower-precipitation of cementite will therefore not originate below the troostite area indicated in Fig. 1. A patch of austenite of variable composition will thus be divided into two areas —the richer, which passes through the troostite area on cooling, yielding troostite, while the less concentrated yields martensite††.

The α-ferrite in troostite is in a relatively soft condition; it does not represent a ground-mass of martensite, but must be supposed to have originated at the high temperature. The formation of this ferrite follows necessarily through inoculation by the cementite particles of the labile shower at some point a little below. It may be anticipated that with higher carbon steels the point Ar' may be divided into two, one belonging to the cementite shower and one of the transformation of the residual austenite by inoculation at a lower temperature.

REFERENCES

(*a*) *On the Supersolubility Curve, Etc.*

1. Miers (H. A.) and Isaac (Miss F.): "The Refractive Indices of Crystallizing Solutions with Especial Reference to the Passage from the Metastable to the Labile Conditions." *Journal of the Chemical Society*, vol. 89, pp. 413-454, 1906.
2. Hartley (H.) and Thomas (N. G.): "The Solubility of Triphenylmethane in Organic Liquids with which it forms Crystalline Compounds." *Journal of the Chemical Society*, vol. 89, pp. 1013-1033, 1906.
3. Miers (H. A.) and Isaac (Miss F.): "The Spontaneous Crystallization of Binary Mixtures. Experiments on Salol and Betol." *Proceedings of the Royal Society*, Lond., A., vol. 79, pp. 322-351, 1907.
4. Jones (R. M.): "The Spontaneous Crystallization of Solutions of some Alkali Nitrates." *Journal of the Chemical Society*, vol. 93, pp. 1739-1747, 1908.
5. Miers (H. A.) and Isaac (Miss F.): "The Spontaneous Crystallization of Substances which form a Continuous Series of Mixed Crystals. Mixtures of Naphthalene and β-Naphthol." *Journal of the Chemical Society*, vol. 93, pp. 927-936, 1908.
6. Isaac (Miss F.): "The Temperatures of Spontaneous Crystallization of Mixed Solutions, and their Determination by Means of the Index of Refraction. Mixtures of Solutions of Sodium Nitrate and Lead Nitrate." *Journal of the Chemical Society*, vol. 93, pp. 384-411, 1908.
7. Hartley (H.), Jones (B. M.), and Hutchinson (G. A.): "The Spontaneous Crystallization of Sodium Sulphate Solutions." *Journal of the Chemical Society*, vol. 93, p. 825, 1908.
8. Hartley (H.) and Barrett (W. H.): "Sodium Sulphite and its Equilibrium with Water." *Journal of the Chemical Society*, vol. 95, pp. 1178-1185, 1909.

†† These remarks relate to the rapid cooling necessary to bring the sample past the condition at which pearlite forms. If, by interrupting the quenching, the steel is held for some time below the troostite area but above the martensite point, troostite will appear, as shown by Portevin and Garvin (28).

9. Isaac (Miss F.): "On the Spontaneous Crystallization and the Melting and Freezing-Point Curves of Mixtures of Two Substances which form Mixed Crystals and Possess a Minimum or Eutectoid Freezing-Point. Mixtures of Azobenzene and Benzylaniline." *Proceedings of the Royal Society*, Lond., A., vol. 84, pp. 344-369, 1910.

10. Miers (H. A.): "An Enquiry into the Variation of Angles observed in Crystals." *Philosophical Transactions of the Royal Society*, Lond., A., vol. 202, p. 515, 1903.

11. Ostwald (W.): "Studien uber die Bildung und Umwandlung fester Korper." *Zeitschrift Physicalische Chemie*, vol. 22, pp. 289-330, 1897.

12. Tammann (G.): "Ein Verfahren zur Erzwingung Spontaner Kristallization." *Zeitschrift Anorganische Chemie*, vol. 87, pp. 248-252, 1914.

(*b*) *On Inoculation and Parallel Growth of Crystals*

13. Barker (T. V.): "Contribution to the Theory of Isomorphism based on Experiments on the Regular Growth of Crystals of One Substance on those of Another." *Journal of the Chemical Society*, vol. 89, pp. 1120-1158.

14. Miers (H. A. and Chevalier (J.): "On the Crystallization of Sodium Nitrate." *Mineralogical Magazine*, vol. 14, pp. 123-133, 1906.

15. Chevalier (J.): "On the Crystallization of Potash Alum." *Mineralogical Magazine*, vol. 14, pp. 134-142, 1906.

16. Barker (T. V.): "On the Regular Growth of Soluble Salts on each Other." *Mineralogical Magazine*, vol. 14, pp. 235-257, 1907.

17. Miers (H. A.): "Note on the Crystallization of Potassium Bichromate." *Mineralogical Magazine*, vol. 15, pp. 39-41, 1908.

18. Barker (T. V.): "The Question of a Relation between Parallel Growths of Crystals and Isomorphous Miscibility, and the Bearing of Parallel Growths on Questions of Isomorphism." *Mineralogical Magazine*, vol. 15, pp. 42-53, 1908.

19. Beilby (G. T.): "Surface Flow in Calcite." *Proceedings of the Royal Society*, Lond., A., vol. 82, pp. 599-605, 1909.

20. Chevalier (G.): "Note on the Spontaneous Crystallization of Drops as Spherulites." *Mineralogical Magazine*, vol. 15, pp. 224-231, 1909.

21. Kreutz (S.): "Contribution to the Study of Parallel Growths of Different Substances." *Mineralogical Magazine*, vol. 15, pp. 232-237, 1909.

22. Barker (T. V.): "Crystallographic Notes on Inosite, Potassium Nitrate, and Urea Nitrate." *Mineralogical Magazine*, vol. 16, pp. 207-216, 1912.

(*c*) *On Steel, Etc.*

23. Chevenard (P.): "Mechanisme de la trempe des aciers au carbone." *Revue de Metallurgie*, vol. 16, pp. 17-79, 1919.

24. DeJean (P.): "Sur la Nature des transformations qui se produisent pendant la trempe des aciers." *Revue de Metallurgie*, vol. 18, pp. 419-427, 1921.

25. Portevin (A) and Chevenard (P.): "Remarques et observations concernant les phenonomenes de trempe des aciers." *Revue de Metallurgie*, vol. 18, pp. 425-444, 1921.

26. Portevin (A.) and Chevenard (P.): "La dissolution retardee et la precipitation prematuree du carbure de fer. . ." *Comptes Rendus*, vol. 173, pp. 1490-1493, 1921.

27. Portevin (A.): "Principes et phenomenes generaux relatifs a la cristallization, a la solidification et a la devitrification." *Revue de l'Ingenieur*, vol. 28, p. 165, 1921.

28. Portevin (A.) and Garvin (M.): "The Experimental Investigation of the Influence of the Rate of Cooling on the Hardening of Carbon Steels." *Journal of the Iron and Steel Institute*, 1919, No. I, pp. 469-559.

29. Ritzel (A.): "Kristallizations- und Auflosungsgeschwindigkeit." *Fortschritte der Mineralogie*, vol. I, pp. 86-98, 1911.

30. Williamson (E. D.): and Adams (L. H.): "Temperature Distribution in Solids during Heating or Cooling." *Physical Review*, N.S., vol. 14, pp. 99-114, 1919.

31. Bowen (N. L.): "Diffusion in Silicate Melts." *Journal of Geology*, vol. 29, pp. 295-317, 1921.

32. Tutton (A. E. H.): "Crystalline Structure and Chemical Constitution." London, 1910.

SOME FATIGUE TESTS OF SPRING STEELS

By R. E. Lewton

Abstract

Fatigue tests and investigations have been the basis of many researches in the past few years. The engineer as well as the metallurgist has been very much concerned with the apparently uncertain factor of the fatigue resisting properties of a given steel. The author of this paper presents some very interesting data obtained in the testing of leaf springs for automotive purposes and outlines the procedure and the results obtained in testing five different types of steels. No mathematical expressions of the relationships between the various factors affecting the ultimate properties of the steels has been formulated.

Introduction

IN THIS paper, the writer has outlined the procedure and subsequent results of a series of tests which were made in the hope of determining a suitable means of comparing different types of spring steels. Whether successful or not, certain observations were made which may be of interest and value.

Fundamental Principles Reviewed

At the outset, it seems desirable to review some of the fundamental principles governing the behavior of metals under loading. When a piece of steel is subjected to a load tending to pull it apart, the piece stretches an amount which is proportional to the load applied. For short lengths, this stretch is imperceptible except with the aid of delicate micrometers. Unless the load applied exceeds a certain value, the piece will regain its original length when the load is removed. If, however, the load used does exceed this limiting value the piece will retain a certain increase in length which is known as "set." Furthermore, above this limit the stretch increases at a much faster rate than before the limit was reached. In other words, there is a point in the loading beyond which the increase of load and increase of stretch are no longer proportional in a definite ratio. This value is commonly called the "proportional limit."

The value for the proportional limit varies with different materials and different treatments but it can readily be determined by suitable laboratory tests. In general, it may be said to occur in steel when the load is ½ to 9/10 of that required to cause failure in the ordinary tension test. All machine and structural parts are designed to work at loads considerably below this limit as experience has shown that even at values much below, there is liability to failure in service. The cause of such failures was formerly considered due to a very indefinite phenomenon called "crystallization," but this explanation has long since been discredited by the experiments of some of our foremost investigators.

These men went about to determine how metal, and especially steel, be-

A paper presented before the South Bend chapter of the society. The author, R. E. Lewton, is engineer in charge of the physical testing laboratory, Studebaker Corporation of America, South Bend, Ind.

haves under repeated stresses, and some surprising results have been obtained. Much has been learned by the use of so-called fatigue or repeated stress machines, particularly those types known as the alternating bend machines. A machine of this type (Fig. 2) was used in the tests about to be described.

Before going into detail as to the operation of the machine, it might be well to consider briefly what happens when a piece of steel is bent. Fig. 1 shows a sketch illustrating a rectangular beam supported at each

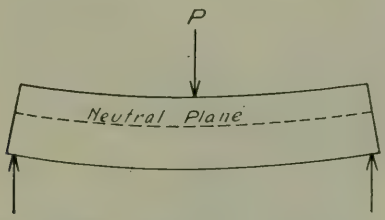


Fig. 1—Sketch Showing the Bending of a Beam When Supported at Either End and Loaded in the Center.

end and loaded in the middle. When the load is applied the upper surface becomes shorter and the lower surface becomes longer while a plane midway between neither shortens or lengthens. Since the lower surface has lengthened the load has acted on that portion of the bar in such a way as to set up tension forces within it. Likewise the upper surface must be in compression. The neutral plane, since it is neither lengthened nor shortened, is neither in tension nor compression. The beam supports the load in the middle by virtue of certain reactions within the bar which are known as stresses. The tension which is in the lower part of the bar and the compression which is in the upper part of the bar is there as a direct result of the application of the load in the middle. Tension and compression then are both forms of stress and are due to the resistance which the bar offers to the load applied. When the load is too great the tension and compression forces or stresses become too great and the bar fails. The point which the author desires to make is, that bending introduces stresses in materials just as does an ordinary tension or compression load. There is this difference, however, that in bending, the tension stresses are not evenly distributed throughout the lower half of the bar but are greatest in those surfaces farthest from the neutral plane and become less and less until at the neutral plane the stress is zero. Also the compressive forces are greatest at the concave surface farthest from the neutral plane and taper off to zero at the neutral plane. This irregular distribution of stress within the bar helps to account for some of the peculiarities of fracture observed in pieces which have failed in fatigue. Since the outermost fibers are under greater stress than those nearer the neutral plane, it is but natural that those fibers should fail first when under load and this is just as true of pieces in repeated stress loading as it is of pieces broken by a single application of load.

When a part fails in fatigue it does not just suddenly break off but failure is a gradual growth beginning at one or more points of weakness. Then as these weaker points give way the load formerly carried by them is thrown upon neighboring particles which may be nearly as weak as those which have already failed.

At one time, the writer desired a special spring made up in a hurry and as the quenching machines were not set up for that particular spring, the foreman volunteered to have the spring made up by hand. The man who regularly did such work was off that day and another was delegated to do the job. When the built-up spring failed at half the life expected of it, and examination was made of the broken plate with the result shown in

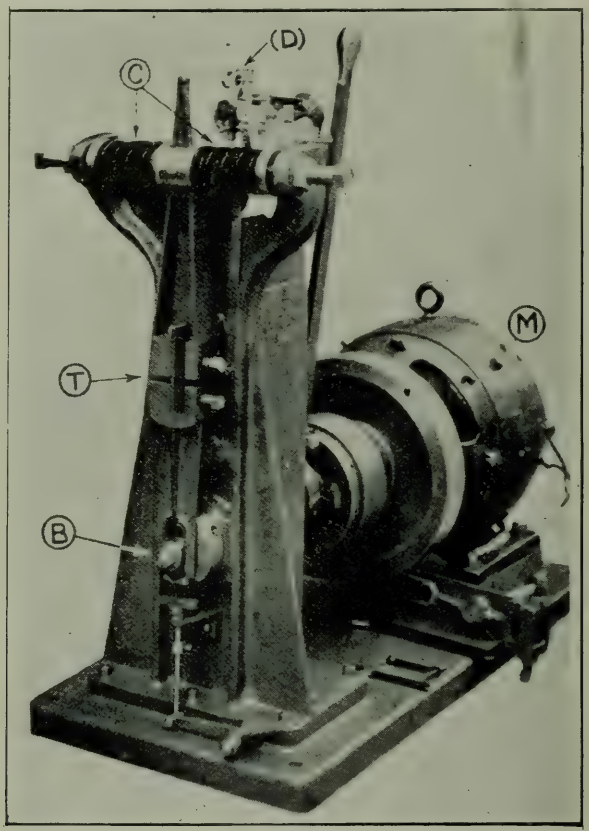


Fig. 2—Upton-Lewis Bend Testing Machine. Specimen is Mounted as at T, Oscillating Cam B, Coil Springs C and Recording Apparatus D.

Fig. 3. It will be noted that the origin of failure of this piece was at the two prick-punch marks. This is one instance which illustrates how small imperfections can cause an early fracture in service.

Apparatus For Making Tests

The Upton-Lewis alternating bend testing machine was used in making the tests described in this paper. It is shown in Fig. 2. The test is made by mounting the test specimen in the clamp jaws as shown at *T* in Fig. 2. The motor-driven cam at *B* oscillates the lower specimen jaw which transmits the strain through the test piece (bending it slightly) to the upper

jaw mounted between two coil springs *C*. The extension to the upper jaw transmits its vibrations to a recording device *D* which keeps a record of the number and amplitude of the vibrations.

From this it is seen that when the test piece is bent first in one direction and then in the other, the outermost fibers are first in tension, then in compression and then back in tension and so on until the piece breaks. The change from tension to compression and back to tension again is called

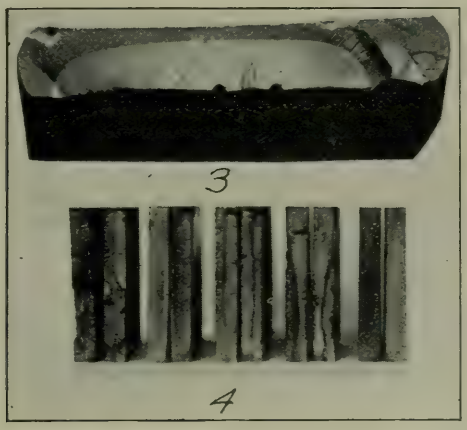


Fig. 3—Fracture of Special Spring. Note that Failure Started at the Two Prick-Punch Marks. Fig. 4—Types of Fractures Usually Obtained on Specimens Tested in the Upton-Lewis Machine.

a cycle and the life of a test is spoken of in terms of cycles. Fig. 4 shows the type of fracture resulting in tests made with the Upton-Lewis machine.

Steels Tested

The tests which are referred to in the introduction of this paper were made on five different types of steel, plain carbon, chrome-manganese, chrome-molybdenum, U. M. A. and chrome-vanadium, the analysis of each

Table I

Chemical Analyses of Steels Tested

Type of Steel	Carbon Per Cent	Manganese Per Cent	Phos. Per Cent	Sul. Per Cent	Si. Per Cent	Cr. Per Cent	V. Per Cent	Mo. Per Cent
Carbon	.91	.45	.020	.035	.11	...	...	...
Chrome-Manganese	.46	.95	.020	.025	.05	.88	...	...
Chrome-Molybdenum	.48	.95	.020	.035	.24	1.22	...	.18
U. M. A.	.46	.85	.020	.018	.14	1.04	.16	...
Chrome-Vanadium	.49	1.00	.020	.022	.26	1.18	.16	...

type being shown in Table I. Bars of No. 1 gauge steel 2 inches wide were obtained and ten or more 5-inch lengths were cut from each. These pieces were then heat-treated and sent to the grinding room with instructions to grind to finish on both faces and edges. No extraordinary care was used

on these pieces except to be sure that the grinding marks did not run crosswise. After grinding, each piece was gripped in the vice and the corners slightly rounded by the use of fine emery cloth, the object being to minimize the possibility of premature fractures originating at the corners.

Heat Treatment

For heat treatment a quenching temperature of 1600 degrees Fahr. was used in all cases. Inasmuch as it is the practice in our shops to quench with the aid of the forming machine it is necessary to go that high if the steel is to be above the critical temperature by the time it reaches the oil. Except for the carbon steel all bars were drawn to a hardness of 418-430 Brinell, using the temperature previously determined experimentally on other pieces. As the carbon steel pieces were only 402 Brinell after quenching they were given the draw which was at that time used in the shops, namely 825 degrees Fahr.; which reduced the Brinell reading to 387.

Results of Tests

Figs. 5 to 9 show in detail, the results obtained on each type of steel tested. Each curve represents the behavior of one of the 5-inch test pieces from the time of the first loading to complete failure. The abscissa of these curves are cycles and the ordinates are termed nominal stress. This means the stress in the piece computed by the usual formula which assumes the piece to be solid until it is actually broken in two. Since in its very nature fatigue failure is a progressive break taking place over a considerable period of time this is not a correct assumption, but by plotting the values so obtained some interesting things are revealed.

Once a test piece begins to fail the experimenter loses control of the stresses in the piece for he has no means of knowing where the failure is nor how large it is, and without this information, has no means of allowing for the change by the proper computations. Fig. 5 shows the curves obtained in the tests on the plain carbon steels. The fact that the piece is weakened is evident on the curves, for the ability of the piece to stand up under the action of the machine becomes less and less until complete failure has taken place.

Figs. 5, 6, 7, 8 and 9 show the history of a series of pieces run to failure at different stresses. In general the higher the stress the quicker the failure, as is to be expected, but as will be noticed by observing how nearly the individual curves approach the dotted line above, it will be seen there seems to be a serious lack of uniformity in the results, especially in the case of the carbon steels.

In interpreting the results of fatigue tests, it has been the custom to plot values for stress against the number of cycles to cause failure. The results of such a plotting of the data just presented are summarized in Fig. 10.

In a sense, Fig. 10 illustrates that steels of the same hardness seem to have similar fatigue characteristics. However, a point which is not shown, is that each curve is only an average and that several points fall wide of the curve as drawn. It is this failure to get uniform results in test pieces which are stressed to a point sufficient to cause failure in a few hundred thousand cycles, which has caused many investigators to abandon and hold as valueless such short-time high-stress curves, and they turn to tests to de-

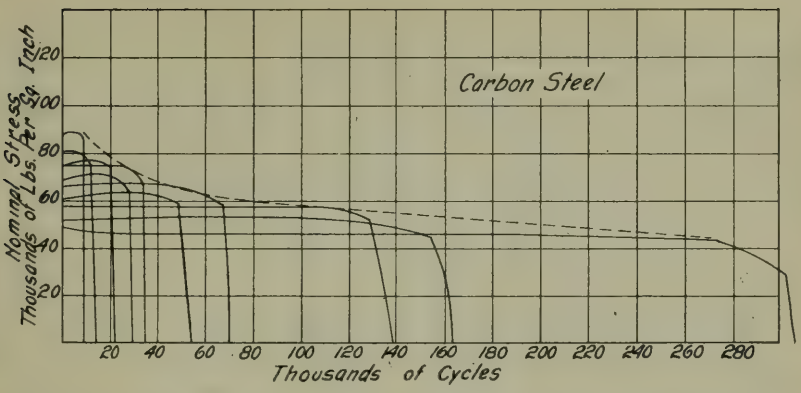


Fig. 5—Curves Obtained in the Tests of Carbon Steel. Steel Quenched from 1600 Degrees Fahr. and Drawn at 825 Degrees Fahr. Analysis of Steel Shown in Table 1.

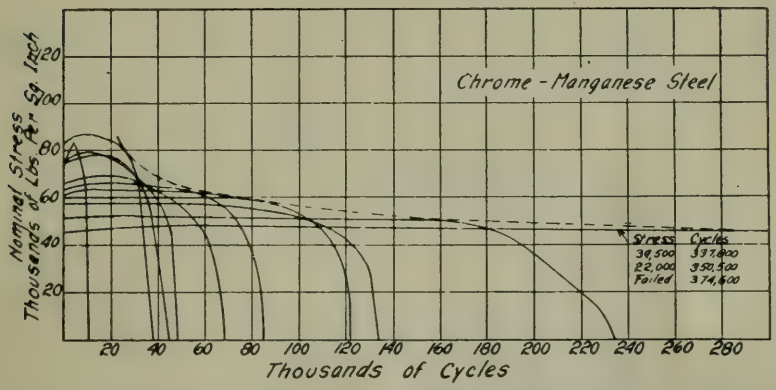


Fig. 6—Curves Obtained in the Tests of Chrome-Manganese Steel, Quenched from 1600 Degrees Fahr. and Drawn at 900 Degrees Fahr. Analysis of Steel Shown in Table I.

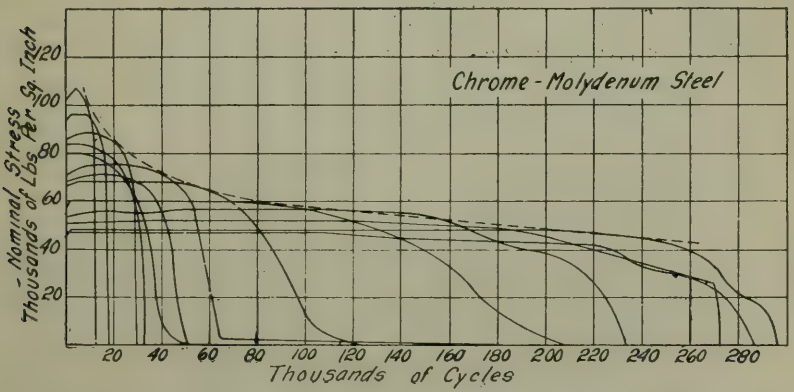


Fig. 7—Curves Obtained in the Tests of Chrome-Molybdenum Steel, Cooled in Furnace After 1 Hour at 1650 Degrees Fahr., Quenched in Oil From 1600 Degrees Fahr. and Drawn at 950 Degrees Fahr. Analysis of Steel Shown in Table I.

termine the fatigue limit or the maximum stress which a material will stand indefinitely without failure.

A study of the curves for the individual pieces as presented in Figs. 5, 6, 7, 8 and 9 shows one important reason why the use of the ordinary stress-life curve is unsatisfactory. For instance, in Fig. 9 it is shown that after two of the pieces were nearly broken off, they seemed to take a new lease on life and continued to hold on for several thousand cycles after failure would have been expected. This is due to the fact already mentioned

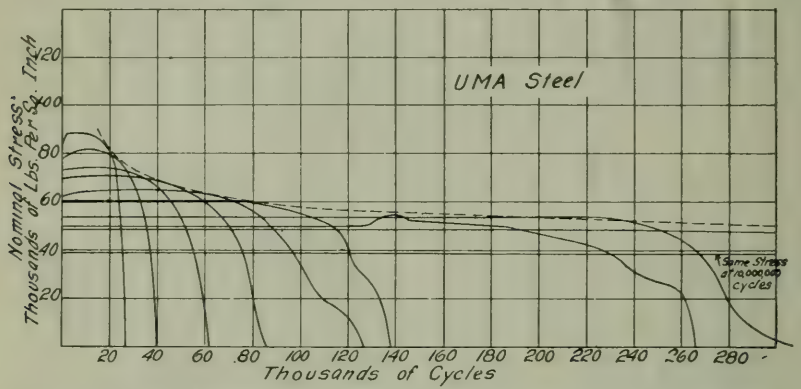


Fig. 8—Curves Obtained in the Tests of U. M. A. Steel, Quenched from 1600 Degrees Fahr. and Drawn at 825 Degrees Fahr. Analysis of Steel Shown in Table I.

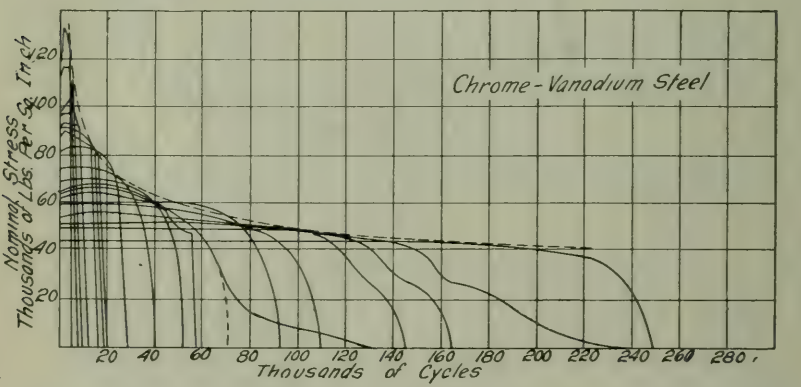


Fig. 9—Curves Obtained in the Tests of Chrome-Vanadium Steel, Quenched from 1600 Degrees Fahr. in Oil and Drawn at 900 Degrees Fahr. Analysis of Steel Shown in Table I.

that once a piece begins to fail, the operator has no control over the stresses actually exerted on the test piece. Due to some undetermined happenings within the piece the stresses are more evenly distributed or of lesser values than were contemplated at the beginning of the run. The life at failure for these two pieces was wide of the curve shown on the stress-life chart. It is interesting in this connection to note that if the curves were to continue in a manner similar to the other curves of the series, the life would correspond very closely to the average stress-life curve.

In view of the fact, however, that after failure begins the observer

has lost control of the behavior of the test piece, and also in view of the fact that after failure has once begun to take place, the material is of no value as a part of a structure, it seems that it would be more instructive to study curves showing the relationship of stress to the life at the point where failure is only beginning. Just where this point is, is hard to determine; in fact, failure under the stresses used in the present tests may be said to begin at the first application of stress. However, in plotting the data here presented, it was noticed that a tangent drawn to the upper part of some of the curves, especially for the chrome-vanadium steel, was also a tangent or nearly so to the curves for the same steel subsequently plotted. Closer inspection shows that tangents so determined touch the individual history curves at points at or just beyond the time when failure begins to be rapidly accelerated.

Fig. 11 shows a comparison of the different steels using the tangential curves. On the face of it, we seem to have arrived at a conclusion op-

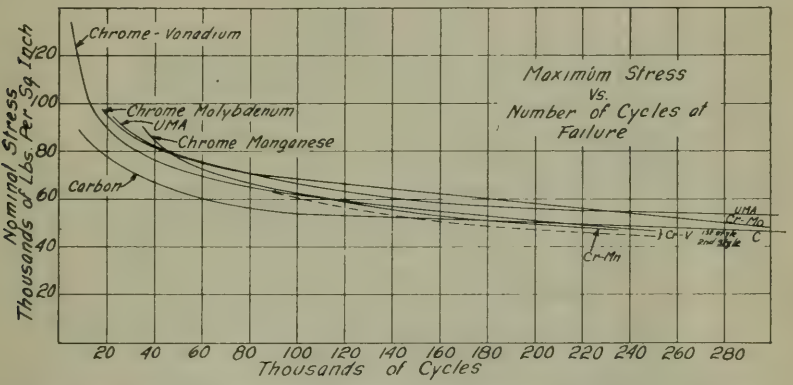


Fig. 10—Results of the Fatigue Tests of Steels Shown in Figs. 5 to 9 Plotting the Values of the Stresses Against the Number of Cycles to Cause Failure.

posite to that which was hoped for. Instead of finding a marked difference in the steels, we find their fatigue characteristics much more nearly the same than was anticipated in the stress-life curves. On the other hand the results tend to substantiate the findings at the University of Illinois (The Engineering Foundation, report for the year ended February 9, 1922, page 64) that the Brinell hardness may be taken as a fair index of the endurance limit. The writer has not determined any endurance limits but it seems reasonable to suppose that the behavior of a material at stresses above the fatigue limit has a definite relation to the behavior at the fatigue limit.

The fact that these tangential curves, then, are shown to give more uniform results than the stress-life curves, and that this uniformity is entirely in accord with the findings of the most recent investigations has led the writer to believe that the tangential curves are a more satisfactory basis for the comparison of the fatigue properties of steels than the usual stress-life curves. Also these curves are more quickly determined as it is not necessary to run the test to complete failure of the pieces.

In what way can such curves be of value?

If any of you were asked what one of the steels discussed in this paper was likely to give the shortest life and which would give the longest under similar service conditions, you probably would all answer "carbon steel"

to the first question and "chrome-vanadium steel" to the second. Now, then, referring to the charts again, as judged by the ability of each and every piece in the series for each kind of steel, to register on the dotted line the carbon steel was the one to give the most irregular results and the chrome-vanadium and U. M. A. steels were the most regular. Chrome-manganese springs have a rather poor reputation and that steel gave irregular results in our tests. The writer has no service records to compare with the findings of this test as regards chrome-molybdenum steel.

This correlation of variations with the known service records for the steels is in accord with the theories as to the nature of fatigue failures as discussed in the Engineering Foundation Report (page 57) from which the following is quoted:

"This theory may be called the theory of non-homogeneity or of localized stress. The effect of external non-homogeneity due to scratches, tool marks, square shoulders, and notches is well known. Internal non-homogeneity

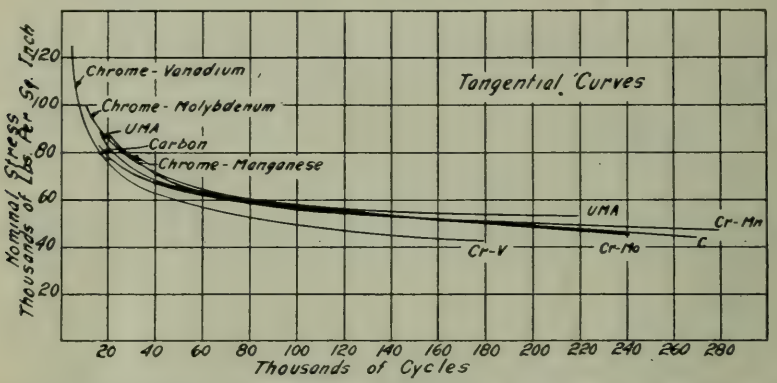


Fig 11—Comparison of Steels as Shown in Figs. 5 to 9 Using the Tangential Method of Plotting.

may be due to blow holes, pipes, inclusion of slag, irregularity of crystalline structure on account of the presence of two or more constituents of varying strength, variation in orientation of crystals or the presence of initial stresses caused by mechanical working or heat treatment. Owing to the minute area over which it exists, this localized stress produces no appreciable effect under a single load, but under load repeated many times, there is started from this area a microscopic crack, at the root of which there exists high localized stress which under repetition of stress spreads until it finally causes failure.

"The writers do not look upon these fatigue failures as being due necessarily to accidental flaws or irregularities. Such failures may, in practice, often be due to such causes, but the definiteness of the endurance limits found in the present tests points to the conclusion that the endurance limit is a property of the material just as much as the ultimate strength. If in these tests the failure is due to flaws, then it is believed that these flaws are an inherent part of the structure of the particular steel which is being tested."

Does it not seem reasonable that the variations seen in the individual curves for the carbon steel and almost lacking in the chrome-vanadium steel are due to these non-homogeneities? And, further, does it not seem reasonable that the more pronounced the lack of homogeneity the greater will

be the variations among the individual history curves for the various pieces? The writer believes that such will be found to be the case.

This reasoning suggests that if some means were evolved to express the variations observed in relation to some value or values accepted as standard we might have a convenient means for the expression of the relative fatigue properties of steels. In the light of the previous discussion, it is believed the tangential stress-life curve offers a suitable standard for this purpose, and that the variations from this standard shown by individual pieces of steel of a given analysis and treatment can be used as measures for the comparison of a steel with other steels and heat treatment with heat treatment.

Conclusion

The writer has not tried to express this relation mathematically, although probably that is ultimately desirable, the limited figures available being hardly sufficient to warrant the attempt. A procedure which might be instructive would be to draw curves more or less parallel to the tangential curves which would be tangential to the curves showing the shortest lives. The area between these two tangents would be of help in comparing the variations in one set of test pieces with the variations in another set.

As to the data assembled and the conclusion drawn, the author is not unmindful that more information is necessary before they are given unqualified acceptance, but the existence of greater variations in the individual curves for the carbon steel than are found in the corresponding curves for the better chrome-vanadium steel is so obvious and so in harmony with the present day theories as to the nature of fatigue failures, that the matter at least seems worthy of further investigation.

Since the charts here shown were prepared we have tested another series of carbon steel test pieces, resulting in a tangential curve somewhat higher than the first one but showing just as marked variations. This latter series was the same as the first in every way except that the draw used was 900 degrees Fahr. instead of 825 degrees Fahr., which would indicate the 900 degrees Fahr. draw to be the better. We are at present running another series of the chrome-vanadium test pieces made from another bar of stock and the tangential curve apparently will fall very close to the one shown. The variations are slightly more noticeable than in the previous test.

DISCUSSIONS OF PAPERS PRESENTED BEFORE THE TECHNICAL SESSION OF THE DETROIT CONVENTION OF THE SOCIETY, THURSDAY MORNING, OCTOBER 5, 1922

THE Thursday morning technical session of the Society's convention held in Detroit Oct. 2-7, 1922, was called to order at 10:15 a. m. by Chairman Dr. C. M. Johnson, director of research, Crucible Steel Co. of American, Park Works, Pittsburgh, Pa.

Chairman Johnson: I will have to apologize for being late in starting. Perhaps it is just as well, because taking into consideration the late hour of the closing of our entertainment last night, we would not have had very much of an audience if we had started on time.

According to our program, the first paper is by H. J. French, physicist of the Bureau of Standards, and Jerome Strauss, metallurgist of the United States Navy Yard, Washington, on "Lathe Breakdown Tests of Some Modern High Speed Tool Steels."

Mr. French: Mr. Chairman and gentlemen, in view of the fact that this paper has been printed in the TRANSACTIONS, I am going to show you the slides that we have representing most of the tables and figures and pass over them rather hurriedly without going into any considerable detail regarding the basis of our conclusions, inasmuch as the complete data has already been presented. This report is in reality a consideration of so-called 'lathe breakdown tests' for the purchase of high-speed tool steel, a method which has been used considerably in recent years at a number of plants. We make no attempt and have no design to compare so-called 'Taylor tests' with the breakdown tests, in which the endurance of tools is measured under fixed working conditions of speed, feed, depth of cut, etc. In making these tests and going over the data obtained, we found certain general characteristics applied to certain types of steel and the classification was based on chemical composition. For that reason, we have first gone into some detail in the chemical anaylsis of high-speed tool steel as manufactured in this country today. (Mr. French then read excerpts from his paper as published in September, 1922, TRANSACTIONS, and concluded with the following remarks:)

I think that will give you a general idea of some of the data which is included in this report. I want to call attention, however, to the statements which we have made in the summary.

Chairman Johnson: You have heard Mr. French's very interesting paper and the exhaustive nature of it is apparent to everybody. I am sure this is a live topic to practically everybody here. I see some in the audience who undoubtedly would call it a vital topic. I hope we can make the discussion snappy, because we have already been late in starting, and it is now five minutes after eleven, so we will have to proceed very rapidly in order to get through with the other papers.

Mr. d'Arcambal: It is indeed gratifying to note that the results obtained by Messrs. French and Strauss check those obtained by us a couple of years ago, when running breakdown tests on side milling cutters. We also found the low tungsten, high vanadium type of high-speed steel to show the highest cutting effect, followed by the 3½ per cent cobalt, 18 per cent tungsten type of high-speed steel. The

tungstenless high-speed steel was also found to show extremely poor cutting qualities in our milling cutter tests.

We were also glad to note that your results showed that the lower tungsten, higher vanadium type of steel did not stand as high a quenching temperature as would the 18 per cent tungsten type of high-speed steels. For lathe tools, however, a slight coarsening of the grain, as would be obtained on quenching this lower tungsten type of high-speed steel from 2350 degrees Fahr. greatly improves the cutting qualities of the tool, for strength and resistance to shock is not required in a lathe tool or tool bit.

We were pleased to note that you consider the analysis of high-speed steel an important factor as regards one of the means of controlling the uniformity of incoming material. Experience has shown us that it is impossible to buy high-speed steel by brands, because of the great range in analysis received in different shipments. While it is true that the analysis of high-speed steel is no indication of its cutting qualities, nevertheless the purchasing of a certain brand of high-speed steel under strict chemical specifications insures us of manufacturing tools of a uniformly good quality.

Tests have convinced us that high-speed tools not running at high speeds, feeds, etc., perform the most efficiently when quenched from the highest possible temperature. The higher the quenching temperature, the greater the solubility of the carbides and tungstides, and the greater the solution of these carbides and tungstides, the better the cutting efficiency we believe.

There are a few questions I would like to ask the authors. First, is the cutting efficiency of tools improved by quenching from the high draw instead of air cooling?

Mr. French: We have made no tests.

Mr. d'Arcambal: Do you believe the temperature of preheating effects the cutting efficiency of the tool?

Mr. French: So far as I know, it doesn't. I have in my files a statement from a manufacturer definitely showing that the preheating temperature, that is, within certain ranges, I believe between 1400 and 1600 degrees Fahr. has no effect on the performance. But we have no conclusive tests regarding that at the present time.

Mr. d'Arcambal: What success have you had with electric furnaces for the heating of high-speed tools? That is, for the high temperatures?

Mr. French: Some of these tools, quite a few of them, in fact, were heated in electric furnaces of the carbon plate type.

Mr. d'Arcambal: Do you consider the electric furnace as successful as the oil or gas-fired furnaces?

Mr. French: Yes.

Mr. d'Arcambal: Are your tools always run dry in service? I notice that no lubricant was used in the tests.

Mr. French: No.

Mr. Spalding: I would like to compliment the authors on this very interesting paper, and I am particularly interested to see that they have found some of the limits of breakdown testing. Now that corresponds a great deal with some of the work we have done. This is of particular interest to me as I have had occasion to run and be connected with the running of a large number of tests of cutting tools

of high-speed steel. I note that the author's method of comparison is to set some definite condition of speed, feed and depth of cut and determine the time of endurance of the tool under these conditions. Examination of the data obtained in this manner indicates, as the authors point out, that results from different tools from the same bar, and different grinds from the same tools, differ quite widely. It is only by averaging results of at least two grinds on several tools of the same steel that a basis of comparison can be obtained. The presence of such wide differences in test performances would indicate that there was some condition in the test that caused this ultra-sensitiveness.

If these conditions could be changed so that individual runs of the same tools would show fairly close checks, it would seem that better comparative conditions would obtain.

The fixing of speed, feed, and depth, and determining the variable time offers the inducement of simplicity of method, but the erratic results obtained do not, I believe, justify its adoption. In our preliminary work we tried the same methods with similar results. Under identical conditions the same tool might run three minutes one time and six the next. Did this mean that one time it was twice as good as another? No. It meant the test conditions were causing an ultra-sensitiveness, giving exaggerated results.

After much perusal of Taylor's "Art of Cutting Metals," in which he found the same thing, we finally adopted his method of fixing depth of cut and feed and determining the speed required to cause the tool to fail in exactly twenty minutes. By this test method we were able to consistently check our results on the same tool or tools from the same bar. We were able to take a bar of steel, make a tool from it, run it, and determine its twenty-minute speed. Then six months from then if we ran this tool again, or another tool from the same bar, we would find that this same speed would cause it to fail in exactly twenty minutes. These results we found we could duplicate on large numbers of different types of tools within five per cent consistently. Although the Taylor method of determining the twenty-minute speed is a little more difficult in operation, still, due to the fact that since consistent results can be obtained, fewer tools need to be run, usually two tools and two grinds are sufficient. The net result is a saving in time and material which is quite considerable if many steels are to be tested.

As far as testing small tools is concerned, we have been able to do that by the Taylor method, but instead of using the same depth, speed and feed as on larger tools, we used the same feed, but a depth of cut that will give us a twenty-minute speed in the neighborhood of the larger tool, as we think this gives a little better basis of comparison.

Referring to the authors' Table XII of the third series of tests, the variations in individual runs in some cases are extreme. One endurance being anywhere from two to five times the other. It occurred to me that perhaps some of this variation might be due to the annealing and rehardening operations; 1550 degrees Fahr. the annealing heat used, is rather low, in my mind, to thoroughly remove all traces of previous hardening. I would not favor annealing and rehardening of tools for

test purposes, as I believe this only serves to introduce further variables. I think we should stick to tools which have been through the fires only once.

Mr. Strauss: In reply to Mr. Spalding's question, we are not holding any brief for the breakdown test. At the same time we would be very glad indeed to have Mr. Spalding submit some of his data as a part of this discussion, so that we might have an opportunity of analyzing it more closely. It is interesting to note that as the severity of the breakdown test decreases, the results become very much more uniform, and when these values and Mr. Spalding's results are reduced to as near a comparable basis as possible, it may tend to show us the causes of the variations which we have observed.

Dr. Hoffman: I would like to ask Mr. d'Arcambal if he has any parallel to the quenching in oil or cooling in air?

Mr. d'Arcambal: You mean quenching from the draw?

Dr. Hoffman: No.

Mr. d'Arcambal: The question I asked Mr. French referred to quenching from the draw, not from the high temperature.

Dr. Hoffman: I have reference to quenching from the high temperature either air cooling or oil, in either lathe or cutting tools.

Mr. d'Arcambal: The large majority of high-speed tools are quenched in oil so as to eliminate as much as posible the excess scaling that would be produced by air cooling; with the possible exception of high-speed saws, which are usually quenched under an air press.

Dr. Hoffman: The information I was trying to get is whether or not, so far as the cutting efficiency of the tool is concerned, one cooled in air showed any better cutting results or efficiency than one cooled in the air blast or one in oil and the other in the air blast.

Mr. d'Arcambal: I don't know, but I really do not believe you would find any difference. It is not so much the rate of cooling as it is the temperature of quenching, that is, the temperature the tool receives before being quenched.

Dr. Hoffman: You don't think there would be any difference, then?

Mr. d'Arcambal: I would hesitate to say so, because we have never conducted comparative tests, but from the theoretical standpoint I see no reason why there would be a difference.

Mr. French: I would like to refer to what Mr. Spalding has said and add also one item to Mr. Strauss' reply. Our tests show that when we have definite working conditions, the speed variation has a marked effect on performance. In the Taylor test the speed is the variable. I would like to know, or have Mr. Spalding give some detailed data as to whether we are really getting any better information when speed is varied to produce more uniform results. If speed changes have such a large effect upon the performance and the speed is varied in the Taylor tests, even though we get uniformity of results, do they really mean any more from the standpoint of the purchase of high-speed steel than comparisons of endurance? I would like to mention again while this discussion has tended toward a comparison of Taylor tests and the breakdown test, we had no idea originally of entering into that. We are simply accepting a test which has been used and examining it for a specific purpose.

Mr. Parker: In reference to the first point in the summary of the authors, I might say that several years ago a breakdown test was conducted in which about six or seven brands of high-speed steel were tried. This breakdown test was run wet, not dry. Steels A, and B, which were first and second in the breakdown test, were then taken and put on test in the shop. Twelve sizes of high-speed of brand A and brand B were taken, and these sizes ranged from quarter inch square to inch and a half by inch, six tools of each size were made and put on production work. The materials cut ranged from soft gray iron through screw stock, up to heat-treated alloy steel of high physical properties. There were ten grinds taken on each of the six tools, and at the end of the test the results were averaged. In every test of the twelve, in which there were sixty grinds, that is, six tools and ten grinds, brand A, which was high in the competitive test, was high in the shop test. And there was some variation, that is, if we take it for granted A was higher than B in the breakdown, say by fifteen per cent, that didn't always follow all down the line. In some cases the superiority of A was more marked than B, and sometimes the difference was not quite so much, but in every case brand A was superior to brand B. Brand A was of the low tungsten, high vanadium type, and brand B was of the high tungsten, low vanadium type.

Chairman Johnson: Our time is getting short, and we will not be able to use any more time for the discussion of this paper.

The next paper, I might say, is right in line with this subject. It is entitled "Carbide Segregation in High-Speed Steel," and will be presented by Col. A. E. White, director of engineering research of the University of Michigan.

Col. A. E. White then presented his paper as published in the January, 1923, issue of TRANSACTIONS.

Chairman Johnson: Gentlemen, you have heard Col. White's appeal for somebody to chase the nigger out of the steel pile. We all realize the immense importance of solving this problem. If somebody has solved it, they may hesitate a little about describing the method, and then again they may not. Are there any suggestions? I think Col. White intended this paper more, as an appeal to intensify research on this subject. But the prize is high enough that I think all concerned are very intensively engaged on the topic as much as their time permits and their research equipment during these times will justify. Are there any comments?

Mr. Muehlemeyer: Col. White's able paper has impressed me because he touched upon a subject that has been a sore spot with the users of high grade steels, especially high speed steel. I had occasion to study European practice some two years ago and as I had heard much rumor of the superiority of European practice to ours I was naturally anxious to see for myself. If European mill practice is capable of producing results superior to ours I failed to see it. Attempts have been made to overcome excessive segregation, which is as much of a drawback there as it is here, by centrifugal casting. This has not been successful as yet. It was also attempted to reduce segregation by casting flat ingots and splitting them afterwards. However, this resulted only in shifting the segregated area. There is no need to enumerate all the ways and means which have been tried to control segregation, suffice to say that it is

still a factor to be reckoned with. From the standpoint of the steel user there is only one way to get around the effects of excessive segregation, which is practiced in Europe as well as here, and that is more thorough inspection of material before shipment from the mill.

Mr. Curran: I fail to see where a diligent inspection will help in eliminating that trouble if they cannot eliminate it in the mill. For instance, if they are going to have 100 per cent segregation, I don't see where they are going to get away from it by inspection. I have noticed, however, that in two papers on the manufacture and treatment of high speed steel published in England in the last three or four years, both by mill men, that they emphasized the elimination of this carbide and tungstide segregation, and both insisted that it is absolutely unnecessary and undesirable. They didn't say how to get away from it though.

All of our experience with domestic high-speed steels indicate that when the size of the bar goes over two inches in diameter it is pretty certain that the structure will show very complete networks of these carbide and tungstide segregations.

Chairman Johnson: One practical aid in this matter, although not from the steel maker's standpoint, but from the customer's standpoint, is a method of cutting of sections, forging of these from a thicker size to a thinner size, cutting a circle from a round or a square from a square piece of a thicker size and getting a good forging to a thinner size. That is used by some with excellent results. That, of course, is after the steel is made and hasn't solved the problem from the melting end at all.

If there are no further remarks, we will take up the next paper by J. V. Emmons, metallurgist with the Cleveland Twist Drill Co., entitled "The Effect of Structure Upon the Machining of Tool Steel."

Mr. Emmons: I am not going to read this paper to you in detail, because it is published on page 1100 of September, 1922 TRANSACTIONS, which you now have in your hands. I will read a few notes and they will give the summary, and we will have the rest of the time for discussion and the asking of questions. (Reads notes)

Chairman Johnson: Before taking up a general discussion, we have this discussion mailed to us by Mr. B. H. DeLong, metallurgist of the Carpenter Steel Co., which I will read as an adjunct to what Mr. Emmons has said.

Mr. DeLong's Discussion

The writer has read with much interest Mr. Emmon's paper as it appears in the September, 1922, issue of the TRANSACTIONS of the Society, and wishes to congratulate the author upon the thoroughness with which this investigation has been carried out. It is interesting to note that he has a good word to say for lamellar pearlite in annealed carbon tool steel, for many of the specifications now written by tool steel users specify that the material must be free from this constituent.

It appears, however, that the value of the paper would have been increased, both from a scientific and from a practical standpoint had details been given of the practice employed in each operation. Types of machines and tools used, speeds at which the metal is cut or worked, size of steel used, etc., are some of the factors that have a

great influence uon the suitability of tool steel for a particular type of machining, as illustrated by the following experiences:

1.—Customer "A" purchases annealed carbon steel bars for the manufacture of cones in ball bearings. Two sizes are used, namely, 1¾ inches in diameter and 1⅜ inches in diameter. Cones from both sizes are turned upon automatic machines. The 1¾-inch diameter is annealed by the steel maker to show a Brinell hardness of about 180 and a scleroscope hardness of 28 to 31. The 1⅜-inch diameter is annealed to show a Brinell hardness of about 160 and a scleroscope hardness of 25 to 28. The micro-structure of each of these sizes varies with the hardness, as illustrated by the author of the paper, but the customer secures the highest possible production from each size only when within the hardness limits specified above.

2.—Steels for Taps—There is a very wide difference of opinion among the manufacturers of taps as to the degree of hardness of annealed steel which will result in most economical production. The Brinell limits specified upon orders for this material range from a maximum of 160 in one case to a minimum hardness of 200 in another case. Various Brinell limits between these two extremes are most often used. Each customer produces taps upon automatic machines, and the requirements of the finished tool as to surface, etc., are the same. Obviously steel having a maximum Brinell hardness of 160 could not have the same structure as steel with a minimum Brinell hardness of 200.

3.—Purchasers of annealed chromium steel for ball bearings specify Brinell hardness requirements varying widely. A list of specifications which the writer has in his files shows the following:

Customer "A"—Maximum Brinell hardness of 170 (Maximum 160 preferred).

Customer "B"—Brinell 160 to 180.

Customer "C"—Brinell 180 to 200.

All this material is used for the manufacture of ball bearing races and is hot-rolled annealed steel. Parts are machined in every case in automatic machines. Each customer is, of course, interested in getting the most economical production from their equipment and finds the Brinell hardness limits set give them the required results.

The writer agrees with the author of the paper that where the quantity of steel involved justifies the expense it is possible to select the most suitable structure for any particular operation with great exactness. He wishes to emphasize the fact, however, that the suitable structure and hardness for the same type of machining will vary greatly in different shops. Care should, therefore, be used not to generalize from the results secured in investigating one type of operation under one particular set of machining conditions.

Chairman Johnson: Gentlemen, is there any discussion on this?

Dr. Mathews: I would like to ask a question or two upon points which I think the paper doesn't make clear. Does this paper deal only with hypereutectoid and carbon tool steels?

Mr. Emmons: Yes, this paper is confined exclusively to hypereutectoid steel and carbon tool steels.

Dr. Mathews: What relation has been found between the best

structure for machining and the best structure for the tool as finally hardened?

Mr. Emmons: (Answering). I would say that the best structure for machining and the structure for producing the best hardened tool, roughly does coincide; that is, both demand in the hypereutectoid steel that cementite segregations and the relics of partially broken cementite network be eliminated so far as possible. Both of them require that the grain size be maintained small. After those two items have been taken care of I would say that the difference in the hardened tool which has been made from what we would call the completely spheroidized structure, and one in which there remains a trace of pearlite, is quite small. There is a difference, however, which might be brought out at this point. If the process of the coalescence or of the gathering together of the cementite into large particles has been carried to such an extent that the round cementite particles are of large size, it then becomes necessary in the hardening operation to allow a longer time at the hardening heat in order to permit the proper solution of these larger globules of cementite. If sufficient time is not allowed, the cementite will not go into solution to produce the maximum hardening effect.

Mr. d'Arcambal: Mr. Emmons' excellent paper on the effect of structure upon the machining of tool steel is the first paper of its kind that the speaker has ever seen published, and fills a much needed want. I have often heard it said that tool steel of a certain Brinell hardness and microstructure is found to be ideal for machining in one plant, but gives trouble to some other concern manufacturing the same class of tools. This statement is verified by comparing the tool steel structure, Fig. 13, and the Brinell hardness range considered ideal for turning, milling, threading, etc., by Mr. Emmons with the structure and hardness of a steel of a similar analysis which is considered ideal by the company I represent.

Experiments conducted some time ago by the Pratt & Whitney Co. indicated that a tool showing a Brinell hardness of from 160 to 190, (170 Brinell preferred, and with the cementite all in the spheroidal form) was the best suited for the different operations such as turning, fluting, threading, etc. Mr. Emmons states that tool steel coming within this range is very difficult to thread and mill at his plant, but we have machined thousands of tons of steel within these Brinell limits, and experienced no difficulty whatsoever with the machineability of the material. Mr. Emmons makes no reference as to the previous treatment the material has received before annealing. My remarks are confined to hot rolled tool steel which has been pipe annealed by the steel mill after the final cogging operation, but I believe that Mr. Emmons' company anneal all of their own tool steel. The finishing temperature the steel has received at the mill also has a great effect upon the resultant microstructure of the annealed material.

Mr. Emmons states that the hardness of the material containing 25 per cent pearlite, as shown in Fig. 13, runs from 190 to 230 Brinell. Our material showing this microstructure has a Brinell hardness of from 180 to 190. Apparently the previous treatment received by the material before annealing is the cause of this difference.

It would also add to the value of his paper if Mr. Emmons would

have gone more into detail as to the different methods of threading referred to. Single point or lathe threading, die threading, chaser threading, hob threading and threading with a thread milling cutter are all methods commonly used throughout the industry. A few days ago we prepared some test pieces of about 1.15 per cent carbon hot rolled tool steel taken from annealed bars of different Brinell hardness. These samples were turned, threaded in two different ways, then fluted, and the slide will show you the results obtained. You will note that as far as turning is concerned, the softer the steel, the better. For the fluting operation, however, material 160 Brinell and under is too soft, and material 195 Brinell and higher is too hard. Steel with a Brinell of from 170 to 187 flutes satisfactorily.

For lathe threading or single point threading, using a spring tool holder, there is no choice between the finish on material running as low in Brinell as 153 or as high as 228. The operator, however, stated that the samples 187 Brinell and higher seemed to be a trifle hard. No burrs were thrown up by the softer steel nor did the tool dig in.

Threading by means of a thread milling cutter, the only sample which showed a rough thread was the material Brinelling 228. The sample specimens referred to in the discussion will be placed on the table for the inspection of all interested in the same.

I would be very much interested in knowing whether Mr. Emmons has ever conducted tests to show the relation between machining qualities and cutting efficiency.

Chairman Johnson: I think we will pass on unless somebody is very anxious to discuss this paper further, and take up the next paper, "A Metallographic Study of Hollow Drill Steel," by Dr. N. B. Hoffman, metallurgist with the Colonial Steel Co. of Pittsburgh.

Dr. Hoffman then presented his paper as it was later published in the January, 1923 issue of TRANSACTIONS.

Chairman Johnson: As our time is getting very limited and many of you wish to attend the ceremonies to be held in Wyandotte this afternoon, we must hasten on to the next paper entitled, "Deterioration of Steel and Wrought Iron in Hot Gaseous Ammonia," by J. S. Vanick of the Bureau of Standards, Washington, D. C.

Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Criticism in This Column—Members Submitting Discussions Are Requested to Give Their Names and Addresses

A DISCUSSION OF ROBERT G. GUTHRIE'S PAPER ENTITLED "THE USE OF VARIOUS KINDS OF LIGHT IN METALLOGRAPHY."

By Herman A. Holz

REFERRING to Robert G. Guthrie's paper on "The Use of Various Kinds of Light in Metallography," published in the April, 1923 issue of TRANSACTIONS, pages 710-719, I desire to make a few remarks, as it contains some statements which should not stand unchallenged on the records of the American Society for Steel Treating.

First of all, light is a substance and as such follows, more or less, the law of gravity. This theory, first offered by Einstein, has been fully proven by the recent investigations of the Lick Observatory.

The use of lightfilters (i.e., monochromatic light) which Mr. Guthrie claims to be imperative for obtaining good micrographs of high magnification becomes necessary only if objectives of poor quality are used. In the application of fully apochromatic objectives which are justly preferred by most up-to-date metallographists, the lightfilters are not at all necessary for perfect results.

As to the resolving power of objectives, immersion lenses of 1.60 N. A. are now available, using monobromnaphthalene (n=1.66) as immersion fluid. If ultraviolet light is used, only glycerine can serve as immersion fluid and the objectives must consist entirely of fused quartz.

The arc produced between magnesium wires has a wavelength of about 280 $\mu\mu$ and produces in many cases such a strong fluorescence that it is possible to focus the microscopic image quite sharply; the cadmium arc of 275 $\mu\mu$ wavelength has similar properties, but yields light of greater chromatic purity. A glycerine immersion objective with N. A. of 1.25 for white light has a relative resolving power of 2.50 if used with light of 275 $\mu\mu$ wavelength.

As to polarized light, its application to metallographic investigations is very valuable, but not in the manner indicated by Mr. Guthrie. In working with polarized light, the specimens should be highly polished, but not etched; the specimen is mounted in the center of a rotating stage and is rotated. No results of value can be obtained by means of an apparatus such as indicated in Fig. 7 of the paper. In the correct use of polarized light no plane glass illuminators or reflecting mirrors should be used, as these are polarizers themselves. No sharp images can ever be obtained by their use.

So far, valuable metallographic work by polarized light has been carried out only on vertical microscopic stands (not inverted), using the Le Chatelier prism illuminator and investigating polished, unetched

specimens mounted on an accurately centered rotating stage. As far as I can see, it cannot possibly be done in any other way if results of practical value are expected. By means of a very simple attachment, every metallurgical upright microscope stand can be made suitable for these investigations.

For photomicrography with polarized light, the achromatic objectives are useless, if an artificial source of light is used, on account of the focal differences otherwise compensated by lightfilters. Only the very best apochromatic objectives set in mountings free from stresses can be used, as every strain in the glass shows up clearly under polarized light. Autochrome plates can be applied to advantage to bring out the effect of the polarized light.

The micrographs Figs. 10 to 13 shown by Mr. Guthrie do not mean very much without explanation of how the magnifications were obtained. Apparent or so-called "empty" magnification by means of oculars or bellows extension has no value; this should not be called "magnification," but "enlargement." Mr. Guthrie states: "the photomicrographs speak for themselves and show of what value they are in the analysis of materials microscopically." This is expressed very diplomatically. I fail to hear these photomicrographs speak, but if Mr. Guthrie would have claimed that they show anything of value, I would have disagreed with him. The micrograph Fig. 13 of 11,000 diameters magnification does not and cannot show a bit more than I can see by taking a pocket magnifier and holding it over picture Fig. 10.

Referring to the closing sentence of Mr. Guthrie's paper, a micrograph such as he mentions can have a practical value solely to people who are very near-sighted. A man with normal eyesight cannot obtain any more information from Fig. 13 than from Fig. 10.

Mr. Guthrie's Reply to Mr. Holz's Discussion

To the Editor:

Referring to the criticisms offered by Herman A. Holz, I wish to state that his communication sounds much as though he had something to sell. It would hardly be necessary to answer his letter if it were not for the fact that he seems to be mixed up on a few points, and no doubt a certain amount of space is allotted to this sort of thing anyway.

In the first place, he mentions light as being a substance, subject to the law of gravity, and as having been offered first as a theory by Einstein, and also mentions the recent investigation of the Lick observatory which appeared in the newspapers not so long ago. The only reason I can see for this first paragraph is that he evidently is attacking the so-called undulatory theory of light, which I mentioned as being the commonly accepted one. The theory that light is a substance was not first offered by Einstein; but be that as it may, there is hardly any doubt that light is a substance the same as electricity is also a substance. However, that has nothing whatsoever to do with the undulatory theory of the propagation of light. The undulatory theory, as has been previously stated, is only the theory of propagation and not the theory of what light is. It is granted that light is a substance, but it is further stated that it is propagated as wave motion.

His next paragraph on the use of light filters assumes, for some reason or other, that the objectives used were of poor quality. As regards this, I

would prefer to refer him to E. Leitz, Inc., of New York. He further assumes that these objectives were achromatic, whereas it happens that they are the very best apochromatic objectives manufactured by E. Leitz, Inc.

Regarding emersion lenses of 1.6 numerical aperture as being available, I should say that I would be very glad to receive literature on them, short mounted and corrected for uncovered objects.

His next paragraph, regarding short wave lengths of light, speaks of the magnesium arc; however, I don't know of any way of applying this method of illumination to metallography, and as far as short wave lengths of light are concerned, it is entirely possible to get even shorter wave lengths than he mentions here by the use of the water cooled tungsten arc.

His next paragraph seems to contradict itself in such a way that I don't know what he means. Furthermore, I don't know how he knows that "No results of value can be obtained by means of an apparatus such as indicated in Fig. 7 of the paper." This work was done merely to find out what could be done in that connection, and I am frank to admit that I don't know of what value it might be to some people, whereas to a majority of people it possibly would be of no value at all, and on the other hand some one person might get a great deal of value out of it. In this paragraph he also states that it is only correct to use polarized light on highly polished specimens. I have examined a great many highly polished specimens before etching, and see the same thing in all of them, namely, a bright, meaningless film; inasmuch as the polishing actually is not one of abrasion but is rather one of wiping or smearing the surface over with a fine film of the softer constituents, I cannot understand just how any value can be obtained from this method. He also goes on to state that "In the correct use of polarized light, no plain glass illuminators or reflecting mirrors should be used, as these are polarizers themselves." I agree, as I think everyone else does, with the statement that mirrors are polarizers; as far as that goes, any mirrored surface may be made to polarize a beam of light.

In the next paragraph, he speaks of a vertical microscope with a Le-Chatelier prism illuminator as the correct apparatus for the use of polarized light or reflecting surfaces. This seems a little mixed up to me, as he mentions in the paragraph previous that no plain glass mirror or reflecting mirrors should be used; however, it is entirely possible to obtain polarized light in the apparatus mentioned in Fig. 7, providing the arm of the inverted microscope, which carries the ocular, is at right angles to the reflecting mirror beneath the vertical illuminator. Any one having this apparatus may prove for themselves that the light is polarized by placing an analyzer over the ocular and slowly rotating it. If the reflected beam is not polarized, it would not react to the analyzer and notwithstanding the previous arguments, it is entirely possible to produce polarized light with either the vertical or inverted microscope. I will, however, agree with Mr. Holz in the fact that in polarized light one should have a perfectly centered rotating stage, and I would further say that in my opinion, humble as it is, all metallographic microscopes should be equipped with a perfectly centered rotating stage. The manufacturers of this sort of equipment would do very well to equip all their metallographic microscopes with the very best and accurate rotary stage that it is practical to build.

The next of Mr. Holz's communication, which deals with high magnification, consists more or less of individual opinion and he is very welcome to them if he so chooses. I did not state that the micrographs, Figs. 10 to 13,

mean any more than they would if taken with the same objectives, but with a short bellows extension. It is very desirable in some classes of work to enlarge the initial magnification considerably that the individual constituents may be more apparent than they are at a lower magnification. It is entirely true, and follows in very natural consequence, that you cannot possibly see anything in a micrograph that is not resolved by the objective, and that for all practical purposes it is not well to go over 1500 diameters with an oil emersion objective of 1.32 numerical aperture. The photomicrographs at 11,000 diameters were obtained merely by the very simple method of using a full camera bellows extension. I might say further that the paper presented before the American Society for Steel Treating was not given with the thought that it presented any new or radical departures from any of the existing methods nor was it a paper intended as an explanation or a complete dissertation on the physics of light, nor on the science of optics. However, Mr. Holz speaks of a great many things that I would like to see done, such as some photomicrographs with an objective of 1.6 numerical aperture using the magnesium arc. It is all very well to mention these things, as regarding what can be done, or what one thinks might be done, but it is somewhat of a different proposition to do them and publish the results so that all may see and benefit thereby.

AUTHOR'S CORRECTION TO DISCUSSION FOLLOWING PAPER ENTITLED "ELECTRIC FURNACE MELTING PRACTICE"

REFERRING to the discussion following the paper entitled "Electric Furnace Melting Practice" by E. G. Stedman, as published in the April, 1923 issue of TRANSACTIONS, page 747, the author has directed our attention to the fact that an error existed in the original manuscript. The twelfth line from the bottom of page 747 should read:

Mr. Stedman: It is cheaper to produce open-hearth, naturally.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment—Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions.

NEW QUESTIONS

QUESTION NO. 82. What analysis steel is most suitable for punching out hot work on upsetter in drop forge shop?

QUESTION NO. 83. In annealing high carbon tool steel in an open fire furnace 6′ x 12′ is it likely that sulphur would be imparted to the steel by the use of producer gas made from coal unusually high in sulphur, say around 1.50 to 2.00 per cent?

QUESTION NO. 84. What is the effect on the steel being forged, through the use of high velocity blows during drop forging?

QUESTION NO. 85. What is the best method of preventing carburization in holes, or in the bore of parts to be case hardened?

ANSWERS TO OLD QUESTIONS

QUESTION NO. 67. What is the reason for the fact that a piece of steel quenched in brine will be harder than the same piece of steel would be if quenched in water, providing that the quenching temperatures and quenching medium temperatures are the same in each case?

ANSWER. By Clifford B. Bellis, metallurgist, the Bellis Heat Treating Co., New Haven, Conn.

The specific heat of brine is greater than that of water, and so the steel is cooled faster. The ability of a liquid to transmit heat depends principally on its fluidity and its specific heat.

As the quenching medium moves past the steel by convection, heat passes from the steel to the contiguous portion of the medium. The rate of this flow depends upon the temperature difference between these two. If the specific heat of the medium is high, the portion contiguous to the steel will rise only slightly in temperature for a given quantity of heat transferred. Therefore, the temperature difference between the steel and the part of the

bath in its immediate vicinity will be greater than if the specific heat of the medium were lower.

A less important reason for the "effectiveness" of a brine quench is that its boiling point is higher and therefore the steam blanket around the steel being quenched is not so great.

QUESTION NO. 69. Is sulphur up to 0.10 *per cent detrimental to the quality and physical properties of an automotive steel?*

QUESTION NO. 71. How do the physical properties compare between a 0.35-0.45 *per cent carbon acid open-hearth steel and an alloy steel of either* 3.5 *per cent nickel or* 1.5 *per cent nickel and* 0.50 *per cent chromium neither heat treated?*

QUESTION NO. 72. What elements are conducive to good electric butt-welding of steels?

QUESTION NO. 73. Does electric butt-welding destroy the physical properties developed in a steel which has been heat treated prior to the welding operation?

QUESTION NO. 74. Why shouldn't a bar of steel rolled from a locomotive axle be better than one rolled direct from the billet made from the original ingot?

QUESTION NO. 76. Why are cold drawn carbon and high-speed steels sometimes supplied with a copper coating? Does this coating affect the steel in any way, or is it merely a lubricating agent in the drawing process? Is it necessary or desirable to remove the coating before hardening?

QUESTION NO. 78. Does microscopic or macroscopic examination of a fatigue failure indicate, even approximately, how long the crack has been forming, or how many times the stress was applied during the growth of the crack?

ANSWER. It is not probable that any microscopic or macroscopic tests will ever indicate the duration of fatigue stresses. An example may be given of a case of fatigue failure in a crankshaft of an automobile engine which had been applied to an ice-cutting machine. In the first year, the company had experienced fifty per cent of failures, due to the breaking off of the fly-wheel end. A specimen of the part broken off next to the fly-wheel end was

given a macroscopic examination, pickled and hot etched to observe if there were any laps or seams visible, and also to study the direction of the flow of the metal. The observation showed that there were no laps or seams and the direction of the flow was satisfactory. The examination further disclosed three entirely separate fatigue fissures which extended nearly half way through the cheek of that particular throw of the crankshaft pin. The actual break had occurred at the shoulder between the cheek and bearing pin. These three fatigue breaks or fissures which had not proceeded to a final fracture were observed very plainly by the microscope. They were located in one-half of the throw, and the throw was found to be split axially or longitudinally. The other half was marked very carefully to indicate where the fatigue fractures were, and the specimens were polished and examined with a microscope. The result was that the crack could not be found.

If the parts were allowed to stand for a while after being polished, a small amount of oil would ooze out of the fissure and form in very small drops and would outline the position and extent of the fissure when a magnification of X 500 was used.

Under the circumstances if the fissure cannot be seen microscopically without some aid, such as the oil that was in the crack, it is believed that there is not much chance of measuring the length of time, or the possible life of the fatigue break by this means.

QUESTION NO. 79. Does the apparent grain size of a fatigue fracture vary with the load applied to cause failure, or with the fatigue strength of the material?

ANSWER. In breaking certain parts by repeated blow where the fracture can be traced almost blow by blow, after the crack has once been started, it can be easily seen that it proceeded by steps of sometimes greater and sometimes smaller length, according to the weight of the blow. It is believed that the roughness of the surface is due to the intensity of the stress to which it is subjected. In observing the breakage of rolls where the fracture takes place starting out through the fillet, where the neck joins the body of the roll, it is not an infrequent occurrence in cold rolling to have the final rupture disclose the fact that there was a small crack existing for some time before, as shown by the discoloration. In that case very little difference in the degree of roughness of the surface can be seen, but where pieces are broken by repeated blows of a hammer or sledge, some of which will be considerably heavier than others, the difference reflected in the length of the steps in the break can be detected.

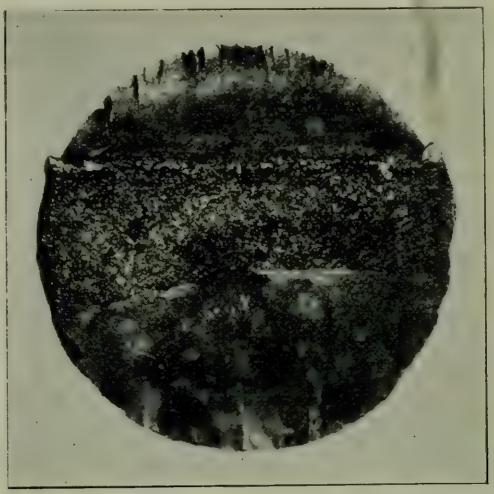
QUESTION NO. 80. Does a banded fatigue fracture indicate interruptions in the growth of the crack?

ANSWER. It is probable that the banded fatigue fracture indicates interruptions in growth of the crack, either due to variable loading or alternating loading or arrested growth of the crack resulting from much lighter loading.

QUESTION NO. 81. How can you distinguish between a fatigue failure in ductile metal and a sudden failure in a metal which was brittle at the time of rupture?

ANSWER. The fatigue failure can be easily distinguished from the

sudden fracture inasmuch as the surface of the fatigue break usually has a silky appearance, while the surface of the sudden break appears jagged and crystalline. Frequently the fractured surface of a fatigue failure will show a combination of two or more types of fractures as is shown in the accompanying illustration. The upper and lower zones of this fracture have the silky appearance of the progressive fatigue fracture while the band across



the center zone is crystalline in appearance, indicating a sudden fracture. This photograph was taken of an automobile steering knuckle which had failed in service. Inasmuch as the principal stresses were in a vertical plane the narrow band across the center was formed in the horizontal direction or normal to the stresses. Usually a brittle metal will break off suddenly resulting in a sparkling crystalline fracture whereas the more ductile metal when subjected to fatigue strains will fail with the silky appearance. This silky appearance of the fracture is the result of the progressive alternating bending and rubbing of the crack walls against each other.

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

SERVICE FOR MEMBERS

The Library Bureau of the American Society for Steel Treating is operated to give to the members quickly, reliably and at the minimum expense the following service:

1. A complete copy of the magazine article referred to in any periodical you may be reading.
2. A translation of foreign articles that would help you with your work.
3. A list of references to books and articles on any metallurgical subject.
4. Informing the members of new articles of interest to them as an engineer.

The Library Bureau makes the entire field of literature available to every member, distance is eliminated, for it will copy the desired information and send it to you. It also helps the busy man by supplying information without any expenditure of his time. The charge for this personal work is merely its cost.

The Library Service does not obtain any profit from the work, but does this to make the information contained in the large libraries with which it has connection available to every member. The rates are as follows:

Photo Print Copies of articles, drawings, etc., 25c per 10 x 14-inch sheets.
Searches, abstracts, etc., $2.00 an hour.
Translations, $6.00 per thousand words for French or German; $7.50 and upward for other languages.
Reference card service, giving reference to current magazine articles, $10.00 a year in advance, and 5c for each card mailed.

Members desiring to avail themselves of this service should address Library Bureau, American Society for Steel Treating, 4600 Prospect Ave., Cleveland, Ohio.

DIFFICULTIES IN HARDENING HIGH-SPEED STEEL. By O. G. Simmons, in *Machinery*, April, 1923, page 627.

In this article the author tells how high-speed steel specimens that would not harden when heated to the specified temperatures in the presence of certain gases would harden by quenching after being heated in an open coke fire, coal fire, a semi-muffle gas furnace or an oil-fired furnace. The author explains the experiments fully, giving several illustrations.

CORROSION OF RUSTPROOFED IRON AND STEEL. By W. P. Wood, Assistant Professor of Metallurgical Engineering, University of Michigan, in *Chemical and Metallurgical Engineering*, April 30, 1923, page 769.

This article states that galvanizing is the best method of protection against rusting when the specimen is immersed in fresh water saturated with oxygen. It further states that the low-carbon steel and the uncoated iron corrode at about equal rates under these conditions.

DROP FORGING PRACTICE. By Leslie Aitchison, in *Forging and Heat Treating,* April, 1923, page 176.

The above was a lecture delivered before the Association of Drop Forgers and Stampers in Birmingham, England, on November 22, 1922. It discusses the principles which determine the size of the bar or billet for use in manufacturing drop forgings. The preliminary forging operations are also discussed in detail.

THE METALLURGICAL MICROSCOPE. By W. M. Mitchell, in *Forging and Heat Treating,* February, 1923, page 106.

This is the second part of an article dealing with the metallurgical microscope which includes a discussion of the various types of illumination and various phases of photomicrography.

The first part dealt with the uses and limitations of lenses.

CASTING IRON IN LONG-LIFE MOLDS. By Richard Moldenke, in *Iron Trade Review,* May 3, 1923, page 1299.

In this article the author tells how the output can be increased by machines equipped with mechanical features; everything being automatic but the pouring operation.

CRITICAL TEMPERATURES FOR ANNEALING GRAY IRON. By Dr. Ing Emil Schuz, *Stahl und Eisen,* September 18, 1922.

The above article discusses the procedure for determining the critical temperature for annealing gray iron, and shows the influence of phosphorus and graphite on hardness. It further shows the importance of pearlite and gives examples of the cementite decomposition.

HEAT CONTROLS IRON STRUCTURE. By E. Adamson, in *Iron Trade Review,* April 19, 1923, page 1156.

This article states that carbon is the main factor in pig iron and is controlled by the physical rather than by the chemical properties. It also states that metallurgists are accepting structure tests rather than the chemical composition. In this article Moissan's work on carbon in pig iron is described.

RECENT ELECTRIC FURNACE DEVELOPMENTS. By Edward T. Moore, Electrical Engineer, Halcomb Steel Co., Syracuse, N. Y., in *Forging and Heat Treating,* April, 1923, page 187.

This article shows that the great demand for any method or device helps to produce development, and this has been especially true with the electric furnace. It describes these developments in detail.

CUTTING DOUBLE HELICAL OR HERRINGBONE GEARS. By Franklin D. Jones, in *Machinery,* April, 1923, page 613.

In this article the author tells how the duplex type of planer may be used for cutting herringbone gears of large pitch. He also shows the application of gear shapers and the end-milling process for cutting these gears.

AUTOMATIC FEEDING DEVICE FOR HIGH-SPEED DRILLING. By Charles E. Bernitt, in *Machinery,* April, 1923, page 621.

This article describes in detail the automatic feeding machine for high-speed drilling, giving illustrations showing the respective parts, and how they are employed.

Reviews of Recent Patents

1,442,213. Metal-drawing Apparatus and Method. Louis H. Brinkman, Glen Ridge, N. J., assignor, by mesne assignments, to General Seamless Tube Co., Bloomfield, N. J., a corporation of Delaware.

This patent relates to a metal-drawing apparatus, which consists of a mandrel for metal drawing, a refractory head, a tube of less refractory material, heat insulation on said tube, a member of less refractory metal than said head, said member having screw threaded connections with head and tube and a passage for cooling fluid adapted to prevent impairment of the threads engaging with said head, said fluid being prevented from coming in contact with said head, and a pipe for cooling fluid extending within said tube.

1,443,580. Electric Furnace. George M. Little, Pittsburgh, Pa., assignor to Westinghouse Elec. & Mfg. Co., a corporation of Pennsylvania.

This patent refers to an electric furnace comprised of a furnace chamber, and terminal electrodes operatively engaging said resistor and projecting through a wall of said furnace, of combined contact terminals and cooling means secured to the outer ends of said electrodes and a stationary cooling means surrounding said electrodes and located intermediate to said resistor and said terminals.

1,443,581. Electric-Resistance Tabular Furnace. George M. Little, Pittsburgh, Pa., assignor to Westinghouse Elec. & Mfg. Co., Pittsburgh, Pa.

The above relates to an electric furnace comprising a heater tube of resistance material divided into sections, a heat-storing means around the tube, compression means to hold the sections together, and means for conducting an electrical current to and from the heater tube.

1,443,816. Electric Furnace. Francis A. J. Fitzgerald, Niagara Falls, N. Y., assignor to Buffalo Apparatus Corp., Buffalo, a corporation of New York.

This refers to an electric melting furnace comprising a furnace chamber oppositely arranged electrodes passing through the walls of the chamber, a holder for each electrode, a right hand operating screw rotatably mounted below one electrode, a left hand operating screw rotatably mounted below the other electrode, an operating arm for connecting each of the screws with one of the electrodes, an operating shaft and means for connecting the shaft with the operating screws.

1,444,062. Process for Producing Stainless Steel. Frank D. Carney, New York city.

This invention relates to a method for making stainless steel which comprises the adding of ferrochrome to a steel and maintaining the melt sufficiently hot to cause a change of the relative affinities of oxygen for carbon and chrominum and thereby cause the carbon to oxidize before the chrominum.

1,444,228. Scleroscope. Gottfried Wirrer, Plainfield, N. J., and Arlington Clinton Moyer, Allentown, Pa., assignor to International Motor Co., New York, a corporation of Delaware.

The above relates to the combination of a machine for testing the hardness of materials, a hammer, an open ended tube in which the hammer moves, devices for supporting the hammer releasably in raised position in said tube including a hook engageable

with the hammer, a cylinder carried on the tube and communicating therewith through an air port, a manually operable piston reciprocable in the cylinder and means engageable by the piston and with the hook for moving the latter out of engagement with the hammer, said piston being adapted to overrun said air port before release of the hammer to place the tube in communication with the atmosphere.

1,444,567. Method of and Apparatus for Testing Materials. Frederick W. Speer, Jr., Oakmont, Pa., assignor to the Koppers Co., Pittsburgh, Pa., a corporation of Pennsylvania.

The above relates to an apparatus for testing materials which comprises a refractory container adapted to contain a sample of the material to be tested, said container having a movable element adapted to be actuated by the expansion or contraction of said sample, and heating means whereby that portion of the container containing the sample may be heated, the heating means and the container being movable relatively to each other to progressively heat the sample.

1,444,584. Electric Furnace Having Resistor Dome. Guilliam H. Clamer, Atlantic City, N. J., and James R. Wyatt, Camden, N. J., assignors to the Ajax Metal Co., Philadelphia, a corporation of Pennsylvania.

This patent refers to an inductive electric furnace, comprising a chamber having an annular electrical conductor with which the pool is adapted to engage at the bottom and which is adapted to overlie the pool at the top in the form of a dome, and a transformer therefor, having one leg passing through the electrical conductor.

1,444,606. Scleroscope. Richard Herrmann, Berlin, Germany, assignor to Schuchardt & Schutte, Berlin, Germany, a firm.

This invention refers to a scleroscope, the combination with a gravity actuated hammer, of a slotted prismatic guide therefor, closed at the open side by a strip of transparent material; and a driver device adapted to return the hammer to its starting position, the driver being carried through a corner of the prismatic guide in manner such that a slot of said guide, intended for its passage, does not extend into the line of contact of the guide with the hammer.

1,444,891. Method for Making Acid-Proof Alloys. Richard Walter, Dusseldorf, Germany.

The method of making an acid-proof alloy is described in this patent. The alloy contains a relatively high silicon content, and over 0.65 per cent of carbon. The process consists of melting down the ingredients and pouring the molten bath at a temperature only slightly above the fusing point of the alloy.

1,444,939. Electric Furnace. Thomas A. Reid, Pittsburgh, assignor to the Westinghouse Elec. & Mfg. Co., a corporation of Pennsylvania.

This patent describes an electric heating furnace. The refractory walls for this furnace are provided with a plurality of spaced-apart relatively narrow, elongated refractory members extending beyond the inner surface of the chamber walls, each having a plurality of spaced-apart transversely extending slots of substantially L-shape adjacent to the inner surface thereof. A plurality of end-connected convolutions of relatively heavy and self-supporting-resistor material located in said slots and extending openly between said refractory members, are provided.

1,444,948. Electric Furnace. Cranston H. Carpenter, Wilkinsburg, Pa., assignor to Westinghouse Elec. & Mfg. Co., a corporation of Pennsylvania.

This patent describes an electric furnace, the combination with a refractory casing, of a muffle of refractory electrical-conducting material in said casing and hoppers in said casing on opposite sides of the muffle. Solid carbonaceous terminal electrodes extending into said hoppers are provided. A mass of electrical-conducting granular material in each of said hoppers adapted to electrically connect said electrodes and said muffle and to permit the current to traverse the walls of said muffle. The said masses of granular material is in contact with the said muffle over a relatively small portion of its surface.

1,444,980. Electric Furnace. William E. Moore, Beaver Pa.; Herbert Franklin Alter, and Edward At Lee Hanff, Pittsburgh, and John Raymond Eckley, New Kensington, Pa., and Frank Wright, Newport, Ky., assignors to Pittsburgh Engineering Work, Pittsburgh, Pa., a corporation of Pennsylvania.

A patent describing a rocking type of electric melting furnace comprising a shell having a tapping spout. Rockers or trunnions are attached to the shell at diametrically opposite points and at right angles to the tapping spout. These rockers are arranged with the rolling surface above the floor line and so formed as to make the stream issuing from the tapping spout travel in paths which meet the receiving vessel at substantially the same point.

1,445,220. Furnace. Charles L. Lee, Dayton, O., assignor to General Motors Research Corp., Dayton, O., a corporation of Delaware.

This patent describes a furnace, comprising a casing, closure means for one end thereof, the closure means being provided with a central opening with a means for centering and securing the work piece within said casing and over said opening a closure. A closure for the other end of said casing is provided and a means for supplying a heating medium through said opening to and within the work piece.

1,445,253. Resistance Alloy. John H. White, Cranford, N. J., assignor to Western Electric Co., Inc., New York city a corporation of New York.

Describing a ferronickel alloy containing more than 60 per cent nickel, in which a portion of the iron is replaced by a material having the properties of tantalum.

1,446,153. Method of Making High-Speed Steel. William B. Brookfield, Syracuse, N. Y.

This patent describes a method of making "high-speed" steel, consisting in subjecting the ingredient element "en masse" to continuous heat sufficient to produce a maximum degree of homogeneity under that heat and afterward resubjecting the product thus formed to another melting heat sufficient to cause a further and more uniform assimilation of said ingredient elements and, therefor, to increase the homogeneity without the addition of other materials.

1,446,497. Alloy. Hugh S. Foote, Pittsburgh, Pa., assignor to Standard Chemical Co., Pittsburgh, Pa.

This patent relates to an alloy consisting of steel having alloyed herewith silicon, manganese, uranium and vanadium in the proportions within the range substantially as specified.

1,446,981. Pouring Mechanism for Refractory Furnaces. Oliver J. Marshick and Edwin L. Crosby, Detroit, Mich.

This invention relates to a machine in combination with a rotatable furnace drum, means on one side thereof adapted to co-operate with a removable external supporting members in constituting a laterally disposed turning axis, and means for lifting upon the opposite side of the drum, whereby the elevation thereof is through an arc whose center is located coaxially with said turning axis.

News of the Chapters

SCHEDULED REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list should communicate with the National Office in order that the list may be as complete as possible.

Boston—Second Tuesday
Bridgeport—Thursday between 20th and end of month
Chicago—Second Thursday
Cincinnati—Second Thursday
Cleveland—Fourth Friday, Cleveland Engineering Society Rooms, Hotel Winton; meeting at 8:00 p. m.
Detroit—Second and fourth Monday, Wing E., 15th Floor General Motors building.
Hartford—Friday nearest 10th of month
Indianapolis—Second Monday
Lehigh Valley—No regular night
New Haven—Third Fdiday
New York—Third Wednesday
Philadelphia—Last Friday
Pittsburgh—First Tuesday
Providence—No regular night.
Schenectady—Third Tuesday
Springfield—Third Friday
South Bend—Second Wednesday
St. Louis—Third Monday
Syracuse—No regular night
Tri City—Thursday
Washington—Third Friday
Rockford—Second Friday following the second Thursday

MEMBERSHIP AND ATTENDANCE CONTEST

The contest is drawing to a close, yet there remains sufficient time for considerable readjustment as is evidenced by the tremendous strides that have been made by a few of the chapters in the past few weeks. It is interesting to note that two chapters have reached the 100 per cent increase in membership, Tri City and South Bend.

A part of the increase for Tri City has been due to the energetic work of the executive committee in securing 13 new sustaining memberships. Besides putting their treasury in a healthy condition, it has put them away ahead in the contest.

Six chapters have had a 50 per cent increase in membership. The following arrangement of the chapters shows the percentage of net increase of

new members based on the number of members each chapter had on September 1, 1922:

	Per Cent		Per Cent		Per Cent
1. Tri City	149.0	10. Syracuse	43.7	19. Indianapolis	19.7
2. South Bend	100.0	11. Lehigh Valley	38.9	20. Chicago	17.9
3. Cincinnati	94.5	12. Schenectady	29.4	21. Washington	17.5
4. Detroit	73.8	13. Rockford	29.2	22. Pittsburgh	16.1
5. North West	69.5	14. Hartford	27.8	23. Providence	13.2
6. Philadelphia	57.7	15. Buffalo	25.0	24. St. Louis	10.5
7. Milwaukee	46.7	16. Toronto	25.0	25. Springfield	10.3
8. New Haven	45.5	17. Cleveland	24.8	26. Worcester	8.9
9. Boston	44.0	18. New York	24.1	27. Rochester	4.8

Attendance At April Meetings

Eighteen chapters reported attendance at April meetings. No attendance report was received from Boston, Chicago, Buffalo, Lehigh Valley, Pittsburgh, Providence, Rochester, Schenectady and Worcester.

The following gives the percentage of attendance at April meetings. Chapters printed in CAPS show an increase in attendance over March meeting:

	Per Cent		Per Cent		Per Cent
1. New Haven	70.0	7. Springfield	36.4	13. Cincinnati	29.4
2. Tri City	64.5	8. St. Louis	35.4	14. Toronto	24.2
3. Rockford	50.0	9. North West	34.0	15. Cleveland	23.7
4. Syracuse	48.4	10. Philadelphia	33.2	16. Washington	22.7
5. Hartford	45.7	11. Milwaukee	32.6	17. Detroit	19.4
6. South Bend	47.6	12. Indianapolis	31.2	18. New York	16.2

Standing of the Chapters in the Contest

On the basis of 50 per cent for average attendance at meetings since December and 50 per cent for net increase in membership since September, the standing of the chapters on May 1 is as follows:

	Per Cent		Per Cent		Per Cent
1. Tri City	100.2	8. Philadelphia	43.2	15. Cleveland	23.9
2. South Bend	76.8	9. Milwaukee	38.4	16. Springfield	23.5
3. Cincinnati	61.9	10. Rockford	35.9	17. St. Louis	21.2
4. North West	53.4	11. Providence	35.0	18. Chicago	20.5
5. New Haven	51.2	12. Hartford	33.5	19. New York	19.0
6. Detroit	49.3	13. Toronto	30.6	20. Pittsburgh	15.9
7. Syracuse	46.2	14. Washington	24.5		

It is to be noted that Tri City, South Bend and Cincinnati are occupying the same positions held in the previous report, while North West has advanced from sixth position to fourth and New Haven has dropped from fourth position to fifth, while Detroit is occupying sixth position.

The percentage of increase in the membership of the Detroit chapter has been quite remarkable and probably denotes the most substantial growth in membership of any chapter, yet because it is the largest chapter in the society the number of those in attendance at the meetings have to be figured against the total membership which brings their percentage of attendance to a low figure, although they have remarkably fine and well attended meetings.

New Members

We have a much better report to make this month as to new members and that is due to the fact that the number of members dropped was much

smaller. There were 89 new members received into the society during the month, while the society suffered a loss of 39 members, 27 of whom were dropped for non-payment of dues and 10 resigned, making a net gain for the month of April of 52 members.

Based on the number of members in each chapter on May 1, the following shows the standing of the 27 chapters of the society. Those printed in CAPS have advanced their position while those that are in italics have a lower position than that occupied in the previous report:

1. Detroit
2. Chicago
3. Philadelphia
4. Pittsburgh
5. Cleveland
6. New York
7. *Hartford
8. *Milwaukee
9. Boston
10. Tri City
11. *Syracuse*
12. North West
13. *Lehigh Valley*
14. Cincinnati
15. *Worcester*
16. Indianapolis
17. South Bend
18. *St. Louis*
19. *Rockford*
20. Washington
21. Buffalo
22. Providence
23. *New Haven*
24. *Schenectady*
25. Springfield
26. Toronto
27. Rochester

*Tied

CINCINNATI CHAPTER

The Cincinnati chapter of the American Society for Steel Treating held its regular monthly meeting on Thursday evening, May 10, at 8 p. m. at the Ohio Mechanics institute. The speaker for this evening was Arthur Townsend, chief chemist, Cleveland Twist Drill Co., Cleveland, who presented a very capable paper entitled "Practical Methods on the Inspection of Tool Steels," illustrated with stereopticon slides. Mr. Townsend having had considerable experience in the inspection of tool steels presented a very interesting and capable paper in which he outlined many of the defects which steels are likely to have. He illustrated his paper with some actual specimens showing some of the typical defects as well as typical satisfactory structures and included in his paper the discussion of the hardening of steels and their inspection by the fracture and macrographic methods. Mr. Townsend's paper was very well received and brought forth a very good and interesting discussion.

Prior to the paper of the evening the chapter held its annual business meeting at which time J. Culver Hartzell was re-elected chairman, Fred L. Martin was re-elected secretary-treasurer and J. H. Nead was elected vice-chairman. Dr. Hartzell read a long report on the activities of the Cincinnati chapter for the past year.

This meeting was one of the best attended meetings of the whole season.

CLEVELAND CHAPTER

The Cleveland chapter of the American Society for Steel Treating held its annual meeting Friday evening, May 25, in the rooms of the Cleveland Engineering society, Hotel Winton, Cleveland. The program for this evening consisted of two papers, the first being presented by R. L. Sanford, director of the magnetic testing laboratories of the U. S. Bureau of Standards, entitled "Magnetic Analysis—A New Method in Metallography." In this paper the speaker outlined in considerable detail the development which has been made in the magnetic testing of materials pointing out its limitations as a routine method of inspection. A very interesting discussion followed

Mr. Sanford's paper which brought out many interesting points of information. The paper was well illustrated with stereopticon slides showing apparatus and curves obtained therefrom.

The second paper on the program was entitled "The Contour Measuring of Threads and Gear Teeth," presented by H. F. Kurtz, assisted by I. L. Nixon, both connected with the Bausch & Lomb Optical Co. Following the presentation of the paper which covered in considerable detail the various methods of obtaining accurate contours Messrs. Kurtz and Nixon gave a demonstration of the operation of the contour measuring apparatus as manufactured by the Bausch & Lomb Optical Co., as it is used in the examination of thread and gear contours. Specimens of threads and gears were placed in the machine and projected upon the screen so that the audience could see their actual contour and mesh.

As this was the annual meeting the officers for the ensuing year were elected. They are R. S. Archer, chairman; C. W. Simpson, vice chairman; D. M. Gurney, secretary-treasurer. Executive committee is as follows: W. F. Abel, J. V. Emmons, E. C. Bartlett, and H. M. Boylston.

Following the meeting a buffet luncheon was served to all of the members and guests. This meeting was exceptionally well attended and proved to be a decided success.

DETROIT CHAPTER

The Detroit chapter of the American Society for Steel Treating held its first regular May monthly meeting on Monday evening, May 14 at 8:00 p.m. in east wing of the 15th floor of the General Motors building, Detroit.

The subject for discussion for this meeting was a paper entitled "Refractories for Heat Treating Furnaces," presented by C. C. Hayward, Service Manager of the Walsh Fire Clay Products Company of St. Louis, Mo. Mr. Hayward illustrated his paper with stereopticon slides and brought out many points of information and interest to the steel treaters, especially the one who is concerned with the design and construction of heat treating equipment. The subject of suitable refractories has been one which has been deserving of considerable investigation and study although apparently the surface has only been scratched. Mr. Hayward's paper brought out many interesting points in which he presented many of the difficulties which confront the manufacture of refractories.

The refractories situation is one of the limiting factors in the metallurgy of iron and steel as well as the metallurgy of some of the nonferrous metals which is today limiting the development of metallurgy. This subject has been given considerable investigation and research but there is still room for a whole lot more.

Following Mr. Hayward's paper a very lively and interesting discussion ensued which brought out many additional points of interest and information to the members who had the privilege of attending this meeting.

The usual get-together dinner was served at 6:30 p.m. in the meeting room and was attended by a large number of members and guests.

The Detroit chapter of the American Society for Steel Treating held

its last meeting of the season on May 29 at the Tuller hotel at 8:00 p. m. The meeting was preceded by dinner at the Hotel Roof Garden at 6:30.

The speaker of the evening was J. V. Emmons, Cleveland Twist Drill Company, who presented an illustrated paper entitled "The Effect of Heat Treatment on the Machinability of Tool Steels."

At this meeting the election of new officers was held and the results will be published in the next issue of TRANSACTIONS.

An interesting entertainment was provided and an enjoyable time was spent by all.

MILWAUKEE CHAPTER

The Milwaukee chapter of the American Society for Steel Treating held its May meeting on Friday evening, the eighteenth of the month at 8:00 p. m. at the Blatz hotel, East Water and Oneida streets.

W. R. Shimer, Bethlehem Steel Company, Bethlehem, Pa., presented a very capable paper entitled "The Manufacture of Steel." This subject was discussed in detail from the iron ore to the finished product, being illustrated with lantern slides, and thus it proved very instructive to all in attendance.

The usual dinner was served at 6:45 p. m. at the Blatz hotel.

NEW HAVEN CHAPTER

The New Haven chapter of the American Society for Steel Treating held a meeting on Friday evening, May 4, at 8 p. m. in the auditorium of the Chase Metal Works, 236 Grand street, Waterbury, Conn.

The topic of the evening was entitled "Some Interesting Phases of Steel Inspection." The speakers were Frank P. Gilligan, Henry Souther Engineering Co., Hartford, Conn., and past president of the society; and T. H. Keshian, metallurgist Waterbury Mfg. Co., Waterbury, Conn. Both of these gentlemen are authorities on the process of acid etching and the paper proved very interesting and instructive to the large number in attendance.

NEW YORK CHAPTER

The New York chapter of the American Society for Steel Treating held held its May meeting on Wednesday, the 16th, in the assembly room of the Merchants association of New York, 9th floor of the Woolworth building.

The paper of the evening was presented by Chas. M. Knight, Jr., of the International Nickel Co., and was entitled "Inspection of Steel." Mr. Knight's paper, which was illustrated with lantern slides, was presented in a very capable manner, discussing the subject in detail. He brought out many points which are of interest to every steel treater. A very lively discussion followed the presentation of the paper.

The usual dinner was served at 6:30 p. m. in the Post Keller restaurant.

NORTH WEST CHAPTER

The annual meeting of the North West chapter was held on Thursday evening, May 17 in the rooms of the Manufacturers' Club of Minneapolis,

200 Builders Exchange. The speaker for this meeting was W. R. Shimer, metallurgist for the Bethlehem Steel Company, Bethlehem, Pa., who presented a very interesting paper entitled "The Manufacture of Steel." Mr. Shimer illustrated his paper with stereopticon slides and traced in detail the manufacture of both carbon and alloy steels from the time it is taken from the ore beds until it is in its final form for use in the many industries.

The North West Chapter were especially fortunate in being able to obtain Mr. Shimer for this occasion who is an authority on the subject of both carbon and alloy steels. Mr. Shimer has had many years experience both in the manufacture of steel and the observation of the many uses to which it is put in the various industries. In addition to outlining the various methods of manufacture of steel he pointed out many of the failures which steel undergoes due to improper design of the components, improper heat treatment; or possibly due to defective steel, containing non-metallic inclusions.

Following Mr. Shimer's paper a lively and interesting discussion ensued which was participated in by many of the members of the North West chapter.

After the presentation of the paper of the evening the report of the nomination committee was read and the election of officers was held. Thos elected to office are as follows: Chairman, H. Kenneth Briggs, Minneapolis Electric Steel Castings Co.; Secretary-Treasurer, Alexis Caswell, Manufacturers' Club. Executive committee: H. A. Anderson, Mahr Mfg. Co.; Thomas L. Joseph, Bureau of Mines, University of Minneapolis; Frank G. Lilygreen, American Hoist & Derrick Co.; Sidney J. Pfaff, Pfaff & Bathke; Wm. I. Sweet, Auto Engine Works.

PHILADELPHIA CHAPTER

The Philadelphia chapter of the American Society for Steel Treating held its regular monthly meeting on April 27, at 8 p. m. in the Engineers' club, 1317 Spruce street.

The program for the evening included a very interesting paper by Dr. Haakon Styri, director of research, S. K. F. Industries, entitled "Melting and Refining of High Grade Steel with Special Reference to the Elimination of Impurities." Dr. Styri described in detail the methods employed in producing clean steel.

The second paper of the evening was presented by John J. Crowe, physical metallurgist, Hull division, Philadelphia navy yard, and was entitled "Pyrometry." Mr. Crowe, who is well known to Philadelphia heat treaters, has made an extensive study of pryometry and consequently gave a very capable presentation.

The usual dinner was served at 6:30 p. m. in the club dining room and was attended by a large number of members and guests.

The May meeting of the chapter was held on the 25th of the month at the Engineers' club.

The program for this evening consisted of a paper by Chas. E. Carpenter, president, E. F. Houghton & Co., entitled "What the Society Means to the Sustaining Member," and W. H. Eisenman, national secretary, spoke

to the members on "What the Society Means to the Executive." There were also short contributions by prominent executives.

A film of motion pictures prepared by the Bureau of Mines at the Cadillac Motor Co.'s plant and entitled "Story of the V Type, 8-Cylinder Motor Car," was an added feature, which proved very interesting.

The election of officers took place at this meeting and the results will be published in the next issue of TRANSACTIONS.

PITTSBURGH CHAPTER

The Pittsburgh chapter of the American Society for Steel Treating held its regular meeting in the Hawaiian room of the Wm. Penn hotel on Tuesday evening, May 1, at 8 p. m. The subject for discussion at this meeting was entitled "Shop Kinks" which was presented and handled by some of the practical shop men, members of the Pittsburgh chapter, who have wide experience in the heat treatment of steel. This meeting was in the nature of a round-table discussion and was conducted by representatives from some of the representative manufacturing companies in and around Pittsburgh, including the Westinghouse Electric & Mfg. Co., the Union Electric Steel Co., the R. D. Nuttal Co., Mesta Machine Co., Crucible Steel Co. and several others.

The points brought out by several of the speakers proved to be highly interesting to those who had the privilege of attending this meeting and many points of practical interest and value were presented.

At this meeting the following officers for the ensuing year were elected: *Chairman*—W. J. Merten, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. *Vice-Chairman*—DuRay Smith, 263 Highland avenue, New Kensington, Pa. *Secretary-Treasurer*—H. L. Walker, Crucible Steel Co. of America, Pittsburgh, Pa. The following *directors* were elected: N. B. Hoffman, Colonial Steel Co., Pittsburgh, Pa.; Prof. S. L. Goodale, University of Pittsburgh, Pittsburgh, Pa.; W. H. Reiger, Union Electric Steel Co., Carnegie, Pa.; L. D. Bowman, Vanadium Alloys Steel Co., Latrobe, Pa.; C. M. Johnson, Crucible Steel Co. of America, Pittsburgh, Pa.; G. L. Kronfeld, Vulcan Crucible Steel Co., Pittsburgh, Pa.; B. F. Weston, Union Drawn Steel Co., Beaver Falls, Pa.; W. B. Crowe, Carnegie Steel Co., Munhall, Pa.; W. J. McInerney, Pittsburgh Crucible Steel Co., Midland, Pa.; B. D. Saklatwalla, American Vanadium Co., Bridgeville, Pa.; R. H. Davis, Firth-Sterling Steel Co., McKeesport, Pa.; W. W. DeGarmo, Union Switch & Signal Co., Swissvale, Pa.; J. M. Camp, Carnegie building, Pittsburgh, Pa.; L. L. Uhler, Union Steel Casting Co., Pittsburgh, Pa.; R. C. Heaslett, Wheeling Mold & Foundry Co., Wheeling, W. Va.

The members of the Meetings and Papers Committee who were elected are as follows: C M. Johnson, *Chairman;* W. B. Crowe, J. M. Lessells, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.; C. I. Niedringhaus, Mesta Machine Co., Pittsburgh, Pa.; J. A. Succop, Heppenstall, Forge & Knife Co., Pittsburgh, Pa.; H. C. Ihsen, Jones & Laughlin Steel Co., Pittsburgh, Pa.

The Membership Committee members are as follows: N. B. Hoffman, *Chairman;* O. B. McMillen, Pittsburgh Rolls Corp., Pittsburgh, Pa.; D. H. Horne, Mesta Machine Co., Pittsburgh, Pa.; G. L. Kronfeld, W. H. Reiger, M. W. Caruthers, 439 Franklin avenue, Wilkinsburg, Pa.; H. L. Walker.

The personnel of the Publicity Committee is as follows: A. N. Armi-

tage, *Chairman,* Mesta Machine Co., Pittsburgh, Pa.; H. Neeb, Standard Chemical Co., Pittsburgh, Pa.; A. M. Cox, Pittsburgh Commercial Heat Treating Co., Pittsburgh, Pa.; H. L. Walker, DuRay Smith.

The following members were elected to serve on the Reception Committee: G. L. Kronfeld, *Chairman;* M. W. Caruthers, W. J. McInerney, and J. K. Miller, 558 Johnston street, Wilkinsburg, Pa.

The following Finance Committee was elected: S L. Goodale, *Chairman;* J. K. Miller, Frank Garratt, Latrobe Electric Steel Co., Latrobe, Pa.; T. D. Lynch, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.; J. Trautman, Jr., Colonial Steel Co., Pittsburgh, Pa.

Those elected to serve on the Entertainment Committee are as follows: D. H. Horne, *Chairman;* W. H. Phillips, R. D. Nuttall Co., Pittsburgh, Pa.; N. B. Hoffman and DuRay Smith.

With this large body of members serving on the committees of the chapter, there is no doubt but that it will have a very successful year.

ROCKFORD CHAPTER

The Rockford chapter of the American Society for Steel Treating held its regular monthly meeting Friday evening, May 18 at 8:00 p.m. at the Nelson Hotel. The speaker for this meeting was H. B. Knowlton of the Milwaukee Vocational School of Milwaukee, Wisconsin who presented a very interesting paper entitled "Carburizing" which was well illustrated with stereopticon slides. As the subject of carburizing had not been discussed before the Rockford Chapter prior to this meeting a very appreciative audience was on hand. Mr. Knowlton brought out many points of vital interest to the steel treater who is engaged in the carburizing of materials, pointing out many of the pitfalls which are apt to be present and which will in many cases result in inferior and perhaps rejected material. Following Mr. Knowlton's paper a very lively and interesting discussion ensued.

After the regular paper and business of the meeting had been taken care of the election of new officers for the coming year was held. This election will be announced in the next issue of TRANSACTIONS.

The usual get-together dinner was served at 7:00 p.m. at the Nelson Hotel and was attended by a good sized number of members and guests.

SPRINGFIELD CHAPTER

The Springfield chapter of the American Society for Steel Treating held its regular monthly meeting on Friday evening, April 27, at 8 p. m. in the Chamber of Commerce rooms, 47 Worthington street.

The paper of the evening was presented by William R. Bennett of the Bennett Metal Treating Co., Elmwood, Conn., and was entitled "Practical Steel Treating." Mr. Bennett spoke with authority on the subject having had many years' experience along this line. His paper dealt with tools, carburizing and heat treatment in general.

SYRACUSE CHAPTER

The Syracuse chapter of the American Society for Steel Treating held its regular monthly meeting on April 26 at the Yates hotel. There were

two sets of motion pictures presented at this meeting, one set was entitled "The Story of the Automobile," and the other "The Story of Alloy Steels." These films proved very interesting to the large number of members and guests in attendance.

The usual dinner was served at the Yates hotol preceding the meeting.

TRI CITY CHAPTER

The Tri City chapter of the American Society for Steel Treating held its regular monthly meeting on Tuesday evening, May 15, at 8 p. m. in the Davenport Chamber of Commerce rooms, Davenport.

George C. Richardson, Bethlehem Steel Co., Bethlehem, Pa., presented a very interesting and capable paper entitled "Manufacture of Steel." This subject was developed in a very interesting manner, with motion pictures tracing the manufacture of steel from the iron ore to the finished product including many of the special alloy steels as well as the carbon steels. In addition to describing in detail the methods used in the manufacture of steel, Mr. Richardson outlined and described many of the failures of finished components due to inherent defects or to improper heat treatment or to the selection of the wrong kind of material for a given component, placing great stress on the importance of the necessity for having clean steel to start with and then properly heat treating this material.

Motion pictures were also presented showing the manufacture of wire and nails as well as the manufacture of steel car wheels.

Following Mr. Richardson's paper a very lively round table discussion, lead by R. B. Kerr, was held on the heat treatment of three typical tools upon which the standards committee of the national society had asked each chapter's opinion.

The usual get-together dinner was served at 7 p. m. in the rooms of the Davenport Chamber of Commerce and was attended by a large number of members and guests.

At this meeting the following officers for the ensuing year were elected: *Chairman,* H. Bornstein, Deere & Co., Moline, Ill.; *vice-chairman,* L. S. Rasmussen, Linograph Co., Davenport, Ia.; *secretary-treasurer,* C. A. Schoessel, John Deere Harvester Works, East Moline, Ill.

WASHINGTON CHAPTER

The Washington chapter of the American Society for Steel Treating held its regular monthly meeting on May 25 at 8:00 p. m. in the auditorium of the New Interior Department buildng.

The paper of the evening was presented by Dr. P. D. Merica, director of research, International Nickel Company, New York City, and was entitled, "Metallurgy and Uses of Nickel." Dr. Merica gave a very capable presentation discussing the extensive applications of nickel in both ferrous and nonferrous metallurgy. He also covered the methods of smelting and refining.

There was a large attendance at this meeting and an enjoyable evening was spent by all.

WORCESTER CHAPTER

The Worcester chapter of the American Society for Steel Treating held a meeting on Friday evening, May 4 at 8:15 p.m. in the Metal Trades Rooms, 44 Front Street, Worcester, Mass. The speaker for this meeting was Victor O. Homerberg of the Massachusetts Institute of Technology who presented a very interesting and instructive paper entitled "The Microscope as an Aid in the Solution of Practical Steel Problems." Mr. Homerberg presented his paper in a practical way and kept away from the highly technical side as much as was possible. He pointed out the many uses of the microscope in determining difficulties which arise in steel due to the many stages of manufacture which it goes through. He pointed out, that in many cases the microscope is the only means of determining certain defects in steel. This paper proved to be highly interesting and was well illustrated with stereopticon slides. Following the presentation of his paper Mr. Homerberg answered many questions and points of discussion. This meeting proved to be highly successful as evidenced by the large number of members and guests who were present.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A repesents Associate Member; S represents Sustaining Member; J represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

NEW MEMBERS

ATKINSON, RHA L., (M-5), U. S. Geological Survey Dept., Interior Bldg, Washington, D. C.
BAILEY, F. J., (M-5), 520 Marquette St., Syracuse, N. Y.
BAUMGARN, ALBERT E., (M-5), 1316 26th St., Rock Island, Ill.
BENSON, A. W., (A-5), 2533 Broadway Cleveland Ohio.
BROWN-LIPE-CHAPIN CO., (S-5), Syracuse, N. Y.
CARHART, RAYMOND, O., (M-5), 623 Oneida St., Syracuse. N. Y.
CONNOLLY, JAS. H., (M-5), Standard Machinery Co., Auburn, R. I.
COOK, J. W., (A-4), 769 S. Central Ave., Los Angeles, Cal.
COYLE, ARTHUR J., (M-5), 934 N. Notre Dame Ave., South Bend, Ind.
CUSTER, GRANVILLE Y., (M-3), 133 N. 4th St., Reading, Pa.
DICKSON, J. C., (M-5), Inland Steel Co., Indiana Harbor, Ind.
DOUGHTY, H. E., (A-4), Atlas Steel Corp., 1420 Penna. Bldg., Philadelphia, Pa.
EAKIN, WM. C., (A-5), 707 Berkshire Ave., Pittsburgh, Pa.
ENGLAND, EARL E., (M-5), 3813 Washington Blvd., St. Louis, Mo.
FLANNERY, MICHAEL, (M-4), Royal Typewriter Co., 150 New Park Ave., Hartford, Conn.
FORSYTH, ARTHUR E, (Jr-5), 1206 5th St., Minneapolis, Minn.
FREYERMUTH, GEO., (M-5), 303 S. Michigan St., South Bend, Ind.
GEARING, CHAS. M., (M-5), New Departure Mfg. Co., Hartford, Conn.
GILLIGAN, JOHN WM., (M-5), P. O. Box 154, Windsor, Conn.
GREGG, JAMES L., (Jr-5), Box 80, Rolla, Mo.
GRUNDLER, HAROLD A., (Jr-2), 1275 E. 115th St., Cleveland, O.
HAJDUCK, S., (M-4), 2705 S. 63rd St., Berwyn, Ill.
HALL, FRANK A., (M-5), M. J. Ryan Co., Wesley Bldg., Philadelphia, Pa.
HAYS, LOUIS B., (A-5), Box 264, Pittsburgh, Pa.
HEATH, JAS. A., (M-5), 291 Devon St., Kearney, N. J.
HENNINGER, A. W., (S-5), New Process Gear Co., Inc., 500 Plum St, Syracuse, N. Y.
E. F. HOUGHTON & CO., (S-5), 612 Putnam Bldg., Davenport, Iowa.
JOHNSON, ADRIAN J., (Jr-5), 2501 5th Ave., Rock Island, Ill.
JOHNSON, OLIVER E., (M-4), 125 St. Paul's Pl., South Bend, Ind.
KNOBLOCK, EUGENE, (Jr-5), 1040 Portage Ave., South Bend, Ind.
KOSTER, J. L., (M-3), Royal Typewriter Co., 150 New Park Ave., Hartford, Conn.
KRON, C. L., (Jr-5), 1812 23rd Ave., Moline, Ill.
MEIER, F. F., (M-5), 5304 N. Front St., Philadelphia, Pa.
PAFFENBERGER, JOHN, (M-4), 1018 Michigan Ave., St. Joseph, Mich.
PARISH, H. C., (M-4), Arthur D. Little, Inc., Cambridge, Mass.
PASCOE, C. F., (M-5), Canadian Steel Foundries, Ltd., Long Point Plant, Montreal, Can.
POTTER, W. WALLACE, (M-5), Potter & Johnson Machinery Co., Pawtucket, R. I.
REUTER, A. E., (M-5), 1419 S. 51st St., Philadelphia, Pa.
ROBERTS, J. P., (M-5), 3039 W. Grand Blvd., Detroit, Mich.
ROHLOFF, JOS. H., (M-5) 6146 Dorchester, St., Chicago, Ill.
RUTTER, CLEMENT C., (M-5), 812 S. Schuylkill Ave., Philadelphia, Pa.
SINDT, ERNEST F., (Jr-5), 1918 Sturtevant St., Davenport, Iowa.
SKOOG, CARL F., (M-5), 2510 Erskine Blvd., South Bend, Ind.
STREET, GEO. L., (M-5), P. O. Box 515, Richmond, Va.
WHITAKER, WHARTON, (M-5), P. O. Box 795, Wm. H. Haskell Mfg. Co, Pawtucket, R. I.
WILLIAMS, J. J., (M-5), 23 Orient St., Meriden, Conn.

WILSON, JAS. M., (M-4), 648 N. 15th St., Philadelphia, Pa.
WUPPER, WALTER P., (Jr-5), 1725 Sturtevant St., Davenport, Iowa.
WYNN, PAUL C, (M-4), P. O. Box 475, Buchanan, Mich.

CHANGES OF ADDRESS

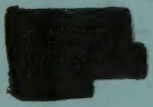
BEELER, CHAS., from 12005 Fairport Ave., to 3188 W. 17th St, Cleveland, O.
BERRY, RUSSELL M., from 1925 N. 11th St., Philadelphia, to 6602 Higerman St., Tacony, Philadelphia, Pa.
BOWERS, WHEELER, from 529 E. 123rd St, to 464 E. 129th St., Cleveland, O.
DESMOND, JOHN J., from North East Electric Co., to 522 Lake St., Rochester, N. Y.
DUMAS, M. G., from 1708 135th St., E. Chicago, Ill., to 17 Townsend St., Pittsburgh, Pa.
FAULK, WM. M., from Yellow Sleeve Valve Engr. Co., E. Moline, Ill., to 1469 Wanamaker St. W. Philadelphia, Pa.
GILMOUR, M. L, from 316 McKinney Ave., to Reynolds Wire Co., Houston, Tex.
HART, ALEX JR., from Amer. Iron Prod. Co., 107 Liberty St., to 44 Whitehall St., New York City.
HOBBS, D. B., from 407 Thorn St., Warren, O., to 2210 Harvard Ave., Cleveland, O.
HOLMES, J. Q. f,rom 1031 N. Pennsylvania Ave., Indianapolis, Ind., to Y. M. C. A., Anderson, Ind.
JEWETT, M. G., from Interstate Iron & Steel Co., E. Chicago, Ind., to 118th & Calumet River, Chicago, Ill.
KARLE, C. E., from 5 Tucker St., Milton, Mass., to 131 Homes St., Dorchester, Mass.
KUTAR, P., from 258 Oakland Ave, Pittsburgh, Pa., to 204 Robinson St., Pittsburgh, Pa.
LEBARRE, R. S., from Interstate Iron & Steel Co., Chicago, Ill., to LeBarre Steel Co., 504 Union Bldg., Cleveland, O.
LEDIN, THEO. E., from 71 Gladstone Ave., to 2902 Vicksburg, Detroit, Mich.
LONGLEY, G. S., from 162 Capitol Ave., to 92 Sharon St., Hartford, Conn.
McKINNEY, H. D., from Driver-Harris Co., 28 S. Jefferson St., to Driver-Harris Co., 564 W . Randolph St., Chicago, Ill.
MILLARD, F. G, from 15412 Center St., to Elk's Club, Harvey, Ill.
MILLER, R. W., from 409 Wilbraham Rd., Springfield, Mass., to 366 Park St., W. Springfield, Mass.
OTTE, CHAS. F., from 7139 Hermitage St., Pittsburgh, Pa., to 7312 Florence Ave., Swissvale, Pa.
PETERSON, J. W., from 448 Underwood St., to River Bank, Riverside Blvd. Rockford, Ill.
PIERCE, PAUL, from 3821 E. Wassington, Indianapolis, Ind., to Ferry Cap & Set Screw Co, Scranton Rd., Cleveland, O.
PRIESTLEY, J. W., from Pittsburgh Crucible Steel Co., Midland Works, Midland, Pa., to 105 S. Lexington Ave., Pittsburgh, Pa.
SCHAGRIN, H., from 1008 E. 42nd Pl, to 1408 E. 69th St., Chicago, Ill.
STENGER, BERNARD H., from Sheldon Axle & Spring Co., Wilkes Barre, Pa., to Queen City Steel Treating Co., Cincinnati, O.
WEBB, GORDON A., from 105 Manistique Ave., to 408 Manistique Ave, Detroit, Mich.
WHYTE, W. C., from Steel Improvement Co., 5003 Windsor Ave., Cleveland, O., to Electro Alloys Co., Elyria, O.

MAIL RETURNED

MUNGAN, J. J., 617 Ford Bldg., Detroit, Mich.

TS
300
A76
v. 3

American Society for Metals
Transactions



ENGINEERING

PLEASE DO NOT REMOVE
CARDS OR SLIPS FROM THIS POCKET

UNIVERSITY OF TORONTO LIBRARY

ENGIN STORAGE